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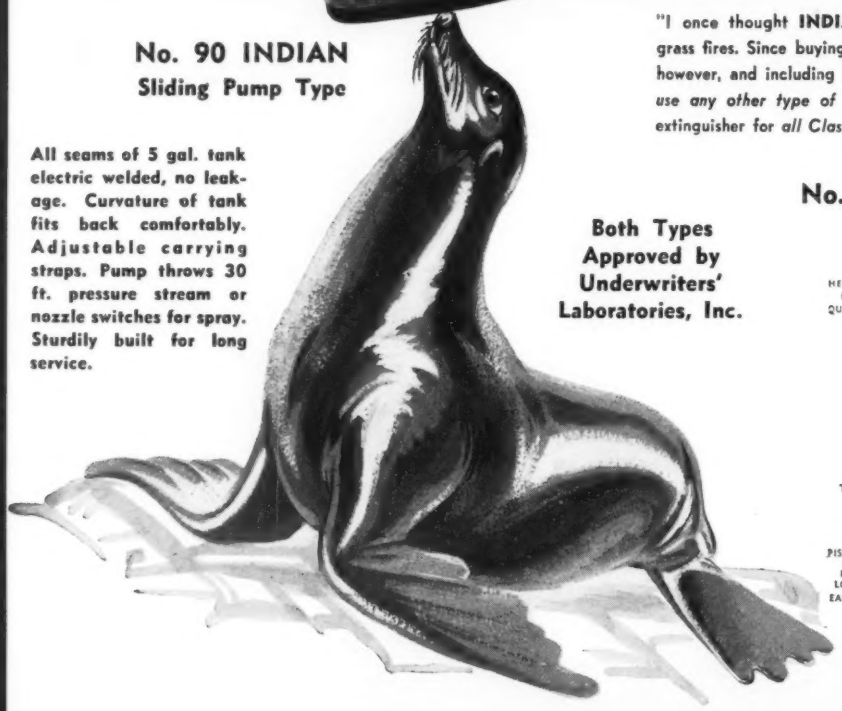

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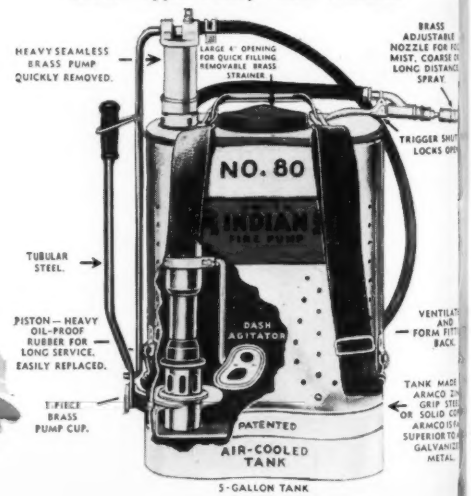
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# Journal of Forestry


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# Genetic Variation Within Geographic Ecotypes of Forest Trees And Its Role In Tree Improvement

Jonathan W. Wright,
R. T. Bingham,
and K. W. Dorman[1]

IN THE PAST DECADE there has been a tremendous upsurge in interest in forest genetics. Some of this interest has centered around species hybridization, some around species introduction, some around provenance testing, and some around polyploidy. But the really big topic has been individual tree variation and its utlization in establishing seed orchards. This paper is a critical review of the philosophy behind this work and the results to date.

In this paper we have purposely been very critical, accepting as proven only those conclusions that can be supported by rigorous statistical analysis. The list of acceptable examples is small, but that is probably due to the fact that this line of work is comparatively new. A high proportion of the acceptable examples bear 1956 or 1957 datelines. We can confidently expect many more such examples in the next decade.

## Individual Variation in Trees as Compared with Crop Plants

As yet forest genetics is too young to have developed a complete literature of its own. We must therefore borrow from the animal and crop-plant geneticists for our estimates of individual variability and genetic gain following the selection and crossing of individuals.

The estimates of genetic gain derived from the short-lived organisms are probably higher than will be observed in the majority of forest trees for two reasons. First, the parental populations of domestic animals and crop plants from which selections are made usually contain less non-genetic variability than do those from which tree selections are made. Rarely in wild forest stands and uncommonly in plantations do we meet with an environment as uniform as is found in experimental cattle herds or experimental corn plantings. Secondly, in most crop-plant breeding programs the innate variability of the parental populations was usually increased by hybridization prior to the start of selection work. Sometimes this was done artificially by crossing selected lines within species. But several of our most important crop and ornamental plants such as maize, tobacco, strawberries, tea roses, dahlias, the New World cottons, and the 21-n wheats originated from species hybridization. Genetic variability is especially large in those crops.

A few of our common forest trees appear to be of hybrid origin. Examples are the pumpkin ash (*Fraxinus tomentosa* Michx.), Rocky Mountain white spruce (*Picea glauca* Moench), Norway spruce (*P. abies* (L.) Karst) from upper Scandinavia, and south Florida slash pine (*Pinus elliottii* Engelm. var. *densa* Little and Dorman). In such genetically variable populations progress following selection should be as great as in hybrid crop plants. However, the majority of commercial tree species such as longleaf pine (*Pinus palustris* Mill.), eastern white pine (*P. strobus* L.), Scotch pine (*P. sylvestris* L.), and white ash (*Fraxinus americana* L.) appear to be non-hybrid origin. If so, the built-in variability and the rate of progress following selection within any local population are likely to be much less than in the case of the hybrid crop plants.

## Individual Tree Selection Versus Geographic Ecotype Selection

Most widespread forest tree species appear to be composed of geographic clines or moderately distinct geographic ecotypes. Examples for which data from replicated and statistically analyzed provenance tests are available are loblolly pine (*Pinus taeda* L.), Scotch pine, white ash, green ash (*F. pennsylvanica* L.), and black cottonwood (*Populus trichocarpa* Torr. and Gray) (*13, 19, 31, 32, 33, 34*). Analyses of variance of the data from the studies cited show that the variation between is significantly greater than that within geographic origins. It follows that full genetic gain can be obtained only by selecting ecotypes as well as individual trees.

Another question immediately arises in connection with ecotype selection. Is not the local population always better adapted to the site than any non-local origin! Some logic says yes, because natural selection has resulted in the best adapted local populations. Some logic says no. Natural selection has favored types which survive and reproduce best but not necessarily types which could produce

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the most usable wood. It has favored types suited to the pre-white man environments but not necessarily to modern environments that include Japanese honeysuckle, white pine blister rust, and strip mining. In glaciated areas the present populations are themselves relatively recent migrants to their present sites and have probably not yet come into equilibrium with their environment. Experimental evidence indicating that local races are best is weak. For example, Rudolf (*22*) stated that in red pine (*Pinus resinosa* Ait.) northeastern Minnesota seed should be used for northeastern Minnesota plantations even though analyses of variance (performed recently by one of the present authors) of the experimental data showed no significant differences among the several Lake States origins tested. On the other hand, the phenomenal success of exotics in Australia, New Zealand, South Africa, and Great Britain, and the superiority of Granite Falls and Darrington stock at various test locations in a Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) study shows the possibilities of the use of non-local stock (*16*).

Good individual-tree selection and crossing programs threaten to be several times as expensive as good ecotype selection or provenance tests. At the start they must include several man-months or even man-years of phenotypic selection work as compared with a few man-months in obtaining seed of different provenances. In individual-tree selection the first generation of progeny tests should be better replicated than provenance tests because the differences to be detected are smaller. At the end of the first generation the ideal provenance test should give nearly all answers needed to supply a true-breeding ecotype for a particular area. At the end of the first generation the ideal individual-tree progeny test should give estimates of per-generation rate of gain and should provide material for the several more generations' work needed to produce a worthwhile new strain. Hence, if there is even a remote possibility that ecotype selection will be productive, adequate provenance tests should be established prior to or simultaneously with the start of the individual tree selection work.

The greater part of the forest planting now being done in the world involves non-indigenous ecotypes. This includes all the Monterey pine (*Pinus radiata* D. Don) planted in Europe and the southern hemisphere; all the *Eucalyptus* spp. planted outside Australia and Tasmania; all the western American conifers planted in Europe; and all the Norway spruce, Scotch pine, and European larch (*Larix decidua* Mill.) planted in the northeastern United States. It includes most of the Baker County (Florida) slash pine (*Pinus elliottii* Engelm. var. *elliottii*) planted in the southeastern United States and most of the Norway spruce and European larch planted in the lowlands of Germany and Denmark. These are instances in which the presently grown ecotypes are not certainly known to be the best available and should not be used as the only bases for long-term selection programs.

The opposite case is illustrated by western white pine (*Pinus monticola* D. Don). Its number one fault is susceptibility to the white pine blister rust (*Cronartium ribicola* Fisch.) which threatens to cause its extinction. Preliminary evidence—the prevalence of the disease throughout the species' range and the presence of occasional single, undamaged trees in heavily damaged stands — indicates that ecotype selection will not provide the answers whereas individual tree selection will.

## Experimental Procedure Necessary to Show the Presence of Genetic Variation within Geographic Ecotypes

There are scores of papers dealing primarily with genetic variation among individual trees. Yet only a few of them deserve mention here. What are the qualifications a paper must have to be admitted to our exclusive "can be trusted" club? We list them below.

1. The conclusions should be supported by evidence from seedling progeny tests or clonal tests. This eliminates such papers as those of Zobel and Rhodes (*35*) and Bouvarel (*4*) which are accounts of the phenotypic variation encountered within natural populations. It also eliminates many recent accounts of seed orchard establishment.

In certain rare instances (cited later in this paper) it is possible to obtain seemingly valid information about genetic variation without the use of progeny tests. Generally the information from such studies is less certain than that obtained from orthodox testing procedures, but it does serve as a guide to future work.

2. Experimental materials must have originated within a definitely circumscribed area and be from the same species. This eliminates several European papers on Scotch pine and Syrach Larsen's examples of clonal variation in Douglas-fir (*11*). These papers deal with differences (apparently not tested statistically) among progenies of unknown or varying provenance. It is probable that they reflect geographic rather than individual-tree variation.

This requirement also eliminates several southern hemisphere papers on Monterey pine (*Pinus radiata* D. Don). That species has a 700-mile-long natural range composed of six non-interbreeding populations and is known to hybridize naturally with Bishop pine (*P. muricata* D. Don) and knobcone pine (*P. attenuata* Lemm.) (*28*). The portions of the genetic variation attributable to species hybridization, geographic variation, and individual tree variation are not separable in work done to date on material of unknown provenance.

Most of the hundreds of papers written on clonal variation in the genus Populus deal with species hybrids and are therefore beyond the scope of this review. We have run across no references giving the results of replicated clonal tests of

variation within local populations of a single species.

3. The experiments must have been replicated and analyzed statistically. We do not accept an author's word that a test site was so uniform that the differences must have been due to genetic factors. Few tree breeders know enough about soils to make such a statement and few soils men would make such a statement. In Michigan we have extensive areas of seemingly uniform, flat, sandy soils underlain by thin clay lenses of varying size. Red pine above one of these lenses grows significantly faster than does genetically similar stock a few feet away. On such a test site how would it be possible to prove or even to guess that the differences among unreplicated plots were due to genetic factors?

The requirements of replication can be waived in experiments involving parent-progeny correlations provided as the progenies are properly randomized.

4. In clonal tests the cuttings or scions should be taken from similar portions of the crowns of all trees tested. Otherwise there is a distinct probability that non-genetic differences associated with position of origin may persist for several years in the vegetatively propagated material and be mistaken for genetic differences. This phenomenon, which is called topophysis, is the basis for the Scandinavian preference for grafting wood from the upper portions of crowns of Scotch pine when establishing seed orchards; the young grafted trees continue to fruit. This prenomenon is widespread, having been found in most instances where suitable tests were made. In European beech (*Fagus sylvatica* L.) scions taken from leaf-retaining branches retain their leaves longer after grafting than do scions taken from leaf-dropping branches (*23*). In Monterey pine differences in growth rate are evident in 5-year-old rooted cuttings taken from different whorls (*25*). Grafts made with scions from vigorous, thornless honeylocust (*Gleditsia triacanthos* L.) and grafts made with scions from thorny branches of the same tree remained respectively thornless and thorny for several years (*5*). Topophysis is extremely common in Hedera, where cuttings made from flowering plants are hardly recognizable as belonging to the same species as those from non-flowering plants. It has also been reported in Citrus, Hevea, Carya, Araucaria, and Populus (*15, 23, 26*).

Except in those rare instances in which an investigator has consistently grafted one clone on one rootstock, possible rootstock-scion relationships do not affect the validity of conclusions reached as to the presence of genetic differences among grafted clones. They merely reduce the precision of such tests.

## Evidence of Intra-ecotypic Genetic Variation in Forest Trees

*From clonal tests.*—The relatively few clonal tests that have been in existence long enough to produce publishable results are summarized in Table 1. Of the experiments listed those on eastern white pine, and European aspen have given the strongest evidence of genetic variation within geographic ecotypes.

Definitive clonal tests such as those of Nilsson (*18*) give information on the relative importance of environment and heredity in the expression of a character. That is about the limit of their usefulness in seed-propagated species such as the pines, spruces, and ashes. Predictions of genetic gain and ultimate selection of the proper parents for seed orchards depend on the results of seedling progeny tests.

*From 1-parent progeny tests.*—One-parent progeny tests are those in which open-pollinated seed is collected from selected female parents; the male parents are unknown. Such tests are inexpensive to install and, if well designed, give reliable estimates of the general combining ability (ability of a parent to give superior progeny in combination with several different males) of the female parents.

An improvement program could be based entirely on the results of 1-parent progeny tests. However, the rate of genetic gain in such a program would usually be far below maximum because half the germplasm in all progenies would be from unknown parents and because general and specific combining abilities are probably never perfectly correlated. Rather, most maximum-gain programs will probably include the testing of both open- and control-pollinated progenies.

The positive results of experiments such as Nilsson's (*18*) on Scotch pine and Norway spruce speak for themselves (Table 2). They indicate rapid rates of progress following phenotypic and progeny selection. The negative results from some experiments deserve explanation. They may indicate either that the species concerned was genetically uniform or that the experimental design used was not adequate. Three types of design deficiencies have been common—inadequate replication, variable test sites, and insufficient numbers of progenies. For example, it can be shown that, for an ecotype of a tree species having the degree of genetic variability apparent in the studies so far recorded, and for some Michigan test sites, it would require a test of about 770 single-parent progenies, each replicated 13 times, to isolate and to demonstrate at the 5-percent level of significance a genetic gain of 1.5 feet over a mean dominant height of 50 ft. at 25 years.

*From 2-parent progeny tests.*—Two-parent progeny tests are those in which both parents are known. Such tests take much longer to establish, but can give much more information than the 1-parent tests. Only from controlled-pollination experiments is it possible to determine the specific combining ability (ability of a particular individual to give superior progenies in combination with other specific individuals) of a tree. Either alone or in combination with 1-parent tests they are necessary for the achievement of maximum genetic gain in a selection program.

TABLE 1.—CLONAL TESTS SHOWING POSSIBLE INTRA-ECOTYPIC VARIATION IN FOREST TREES. DEFIENCIES IN EXPERIMENTAL DESIGN WHICH PREVENT ACCEPTANCE OF THE DATA AT FACE VALUE ARE SHOWN BY ITALICS

EUROPEAN BEECH (*Fagus sylvatica* L.).—Tellerup and Schaffalitsky de Muckadell (*29*) reported differences in stem form and narrowness of wood rays *in unreplicated tests of ortets collected from unstated positions in the crowns.* The ortet-ramet correlation was not significant.

EUROPEAN ASH (*Fraxinus excelsior* L.).—Larsen (*11*) reported clonal differences in four characteristics *in unreplicated* tests of three grafted clones of *different geographic origin and unstated location of the scion wood in the parent trees.*

GREEN ASH (*F. pennsylvanica* Marsh.).—There were clonal differences in leaf hardiness among half sibs in *unreplicated tests.*[1]

NORWAY SPRUCE (*Picea abies* (L.) Karst.—Larsen's (*11*) reports of clonal differences between two grafted clones are based on *unreplicated tests of ramets iollectèd from unknown provenances and unstated positions in the crowns.*

MONTEREY PINE (*Pinus radiata* D. Don).—Fielding's (*8*) reports on clonal differences in 15-year height, disease insect resistance, spiral grain, form factor, stem straightness, and number of whorls per year's growth are based on experiments conducted with ramets of *unknown provenance and unstated position in the crown. Presence or absence of replication was not stated.*

EASTERN WHITE PINE (*P. strobus L.*).—Riker et al. (*21*) and Ahlgren. (*1*) found that only 4 percent of the grafted ramets from rust-free ortets were cankered whereas the *seedlings used as controls* were heavily attacked by white pine blister rust (*Cronartium ribicola* Fisch.).

SCOTCH PINE (*P. sylvestris* L.) Nilsson (*18*) and Schütt (*24*) reported statistically significant ortet-ramet correlations in branch angle, branch size, bole form, and resistance to needle cast. Arnborg and Hadders (*2*), in *unreplicated tests including material from different geographic ecotypes,* reported striking clonal differences in several important characters.

EUROPEAN ASPEN (*Populus tremula* L.).—The *gigas* triploid clones first described by Müntzing (*17*) have subsequently proven to be faster growing than diploids.

DOUGLAS-FIR (*Pseudotsuga menziesii* [Mirb.] Franco). —Larsen's (*11*) descriptions of clonal variation in three characteristics are based on *unreplicated tests of ramets collected from different geographic origins and unstated positions in the crowns.*

WESTERN RED-CEDAR (*Thuja plicata* D. Don).—Larsen's (*11*) descriptions of clonal differences in 10-year height and winter hardiness are based on *unreplicated tests of ramets collected from different geographic origins and unstated positions in the crowns.*

[1]Northeastern Forest Experiment Station, unpublished data.

TABLE 2.—SEEDLING PROGENY TESTS GIVING RELIABLE DATA ON INDIVIDUAL TREE GENETIC VARIATION

EUROPEAN BIRCH (*Betula verrucosa* Ehrh.).—Johnsson (*10*) reported the presence of from 1 to 52 percent flame-grained seedlings in wind- and control-pollinated progenies of flame-grained parents.

NORWAY SPRUCE (*Picea abies* (L.) Karst.).—Nilsson (*18*) found significant positive correlations ($r = 0.35$ to $0.49$) in stem form between parental phenotype and wind-pollinated progeny means.

SLASH PINE (*Pinus elliottii* Engelm.).—The progenies of trees selected for high oleoresin yield and for long tracheids differed significantly among themselves and from the progenies of average trees (*7, 9, 12*).

WESTERN WHITE PINE (*P. monticola* D. Don).—Squillace and Bingham (*27*) found statistically significant correlations between periodic annual increment of the parents and height of the progenies. The correlations were higher for control-pollinated than for wind-pollinated progenies. The progenies of phenotypically resistant parents differed significantly among themselves and from the progenies of average parents in percentage of seedlings resistant to blister rust[1]. For both characteristics the indicated rate of gain following phenotypic selection alone was small; it was highest for phenotypic selection followed by 2-parent progeny tests.

EASTERN WHITE PINE (*P. strobus* L.).—Riker et al. (*21*) reported no significant differences in blister rust resistance between wind-pollinated progenies of resistant parents and progenies of average parents.

SCOTCH PINE (*P. sylvestris* L.).—Nillsson (*18*) found significant correlations ($r = 0.56$ and $0.58$) in stem form between parental phenotype and wind-pollinated progeny means. Børset (*3*) found significant differences among six wind-pollinated progenies in several characters; parent-progeny correlations were not significant.

LOBLOLLY PINE (*P. taeda* L.).—Minckler (*14*) found significant differances in 5-year height among wind-pollinated progenies of 103 parents. The parent-progeny correlations were not significant, possibly because of inattention to seed weight effects.

GOLDEN LARCH (*Pseudolarix amabilis* (Nels.) Rehd.).—Two selfed progenies of this limited-range exotic differed in time of leafing out[2].

[1]Northern Region and Intermountain Forest Exp. Sta., Forest Service, U. S. Dept. Agric., unpublished data.

[2]Northeastern Forest Expt. Sta. Forest Service, U.S. Dept. Agric., unpublished data.

The results of the few 2-parent progeny tests summarized in Table 2 are impressive. In western white pine the percentage of seedlings that are resistant to blister rust could be raised from 5 to 29 percent in a single generation by the use of the four best progeny—tested parents. Some of Johnsson's (*10*) control-pollinated progenies could be used immediately for the commercial production of flame-grained European birch (*Betula verrucosa* Ehrh.)

The 2-parent progeny tests could be, but have not been, subject to the same design deficiencies as the 1-parent tests. For one thing the between-progeny differences were larger and detectable with less replication. For another thing, there was such a large initial investment in control-pollination time that more attention was paid to obtaining proper replication and precision.

*From taxonomic and horticultural experiments.*—The taxonomic and horticultural literature is a largely neglected source of information about genetic variation in forest trees even though it contains scores of examples for every example contained in the forestry literature. Rehder (*20*), for instance, lists 32 forms or varieties in the single species northern white-cedar (*Thuja occidentalis* L.).

This literature, however, has its limitations. Usually no effort has been made to distinguish between local variants, selfs, species hybrids, polyploids, geographic variation, and topophytic phenomena. Too, most of the variants described by horticulturists grow more slowly than normal and are therefore of limited interest to foresters. However, this literature is very strong in one respect. Nearly all forms and variations accepted by taxonomists for inclusion in modern taxonomic manuals have been proven to come true by grafts or cuttings in growth trials in numerous localities.

The taxonomic literature contains very little information on inheritance, as most of the variants have been reproduced in limited quantities asexually. However, there are a few instances— for example the Sargent weeping hemlock (*Tsuga canadensis* L. var. *pendula* Beiss.)—in which the variant is known to occur in moderate numbers in the seedling progeny.

*From other types of experiments.*—The human geneticist has control over the matings of only two individuals. And sometimes not so much control at that. How, then, has he assembled as much information as he has on the inheritance of several hundred characters? He has had to resort to various dodges, such as studying the similarities between twins or the expected and observed frequencies of abnormal children in families containing two or more children.

Can we apply some of the human geneticists' techniques to the study of forest trees? Yes, it has been done successfully in certain exceptionally favorable circumstances. Downs (*6*) found strong evidence for genetic control of forking in white oak (*Quercus alba* L.) in a study of the degree of similarity of pairs of stems in small sprout clumps. Some of the Lake States tree breeders such as Scott S. Pauley and Philip N. Joranson are using quaking aspen's (*Populus tremuloides* Michx.) tendency to reproduce by root suckers to study qualitative clonal variation in that species. In the spring and autumn small phenological differences among clones make the delimitation of the clones on the ground and the study of other characteristics of the clones a simple matter. Toda (*30*) estimated heritability of several characteristics in *Cryptomeria japonica* (L. f.) D. Don by analyzing the variances of clonally and sexually reproduced stands. If this assumption of equal site variability in the two strands is correct, selection in this species should be very effective. One of the present authors found that in jack pine (*Pinus banksiana* Lamb.) the percentage of open-coned trees was much greater in natural reproduction than in three unburned parental stands, indicating natural selection in favor of early cone opening in unburned areas.

Such studies as these are advantageous in that they take days rather than years to consumate. They have their limitations, also. Some of these limitations can be lessened or eliminated if recognized and guarded against. For instance, Toda's data are not incontrovertable evidence of genetic variation because they rest on the assumption that the site variability was similar in both stands studied. Replication by studying several seedling stands and several clonal stands would eliminate that source of error.

## Putting Intra-ecotypic Variation to Work in Tree Improvement

*In naturally reproduced stands.*—There are several reasons for believing that most genetic improvements will take place in widely planted species and that the tree breeder will contribute little to the genetic improvement of naturally reproduced stands. First, in naturally reproduced stands we can practice only phenotypic selection, which may be quite ineffective if most of the genetic variance is nonadditive. Second, in areas in which natural regeneration is apt to be practiced the coefficient of environmentally induced variability is rather high and the heritability of tree characteristics correspondingly low. Third, the selection differential (superiority of the selected over average parents) must be fairly high—two or three standard deviations—to cause appreciable improvement. The attainment of a selection differential of two or three standard deviations means leaving only the best one out of 44 or 769 trees respectively. Ordinarily this is too severe for even a "scattered seed tree" cutting.

The fourth reason for not claiming a large role for genetics in the improvement of naturally regenerated stands is that intensive silviculture can accomplish the same objectives as genetic selection. Reserving the best individuals in the course of intermediate cuttings is just as constructive a step as reserving such individuals for seed trees when making the reproduction cutting, and is, indeed, a prerequisite to full effectiveness of the latter step. Furthermore, the reservation of superior individuals in the early intermediate cuttings, with sure phenotypic gains 10 to 30 years hence, is easier to justify than a "genetic" harvest cutting with problematical gains 40 to 100 years hence.

*In planted stands.*—In contrast, the possibilities of utilizing intra-ecotypic variation for the genetic improvement of planted species are great. In this connection we should be guided more by the favorable results than by the negative results because most of the experiments giving only negative results were inadequate even to suggest that the species concerned were genetically uniform. We are as yet in no position to state the maximum degree of improvement that can be expected from strong selective breeding programs.

How will we obtain this genetic improvement of planted species? By selecting the best all-around trees and using their seed (phenotypic selection)? By selecting the best trees, propagating them clonally, and distributing cuttings (clonal selection)? Judging from agricultural experience and the data in Table 2, either of these methods alone will produce meager results. The most significant probably will come from programs in which every parent is carefully selected and carefully progeny-tested and in which controlled pollinations play a major role.

When can we expect worthwhile new varieties to replace the ordinary planting stock we now use? We should humbly remember that tree breeders as a group possess less combined experience than may sometimes be found in the genetics department of a single large university, and that woody plants are not as favorable experimental material as maize or wheat. Therefore, since several generations have been

required for the development of most crop plant varieties, we may expect to have to spend at least two or three generations developing appreciably better new tree varieties. Fortunately there are a few short cuts available such as juvenile selection for certain characteristics. Also, fortunately, a tree breeder can work on several different projects concurrently, so that, after an initial wait is past, results can be expected regularly.

## Summary

Experiments on genetic variation within ecotypes of forest trees started in earnest after the end of World War II. During the ensuing 13 years a tremendous literature has developed on the subject. However, disappointingly few of the experiments described have been adequate to prove the existence or non-existence of such variation, and fewer still have been adequate to provide estimates of the relative amounts of genetic variation present.

This does not mean that genetic variation sufficient for the end we have in view—improvement of our forests by selecting and breeding outstanding individuals—is lacking in American forest trees. It does mean that as yet we have little proof of where it exists, or to what extent. We need this proof before our genetic "action programs" can run at top efficiency.

The most reliable data on individual-tree variation are from Scandinavian experiments on Scotch pine and Norway spruce and from western American experiments on western white pine. In all three species the indicated amount of genetic variation is great —large enough to permit us to make optimistic estimates of rate of progress following intensive selection and breeding programs.

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# Benefits from Hybridizing American Forest Tree Species

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THE FORESTER not actively associated with forest tree improvement may ask why the intercrossing of species often occupies such a prominent place in the program of forest tree breeders. Several sorts of motives are responsible.

One sort may be termed economic or utilitarian; that is the principal theme of this paper.

Curiosity and a desire for novelty constitute a second sort, strongly operative in the early stages of numerous tree improvement programs. While our experience leads us to expect the offspring of two slash pine trees to be just another slash pine tree, we are likely to be quite curious about results of crossing an evergreen oak with entire leaves and a deciduous oak with deeply cleft leaves.

Then, there are what may be termed technical motives for emphasis on hybridization.

When a breeder starts work with a group of plants, he is likely to be unsure of his methods. How much better to observe progeny in which signs of hybridity are vivid as, in species crosses, than to observe progeny from a mating of two similar parents from within a species!

Finally, there are scientific reasons for species hybridization. Among these is the prospect of furthering the basic knowledge of the genetics of forest trees which will be so necessary for their ultimate improvement. The breeder is not usually provided, as was Father Mendel, with green wrinkled peas to cross with yellow smooth peas. Yet tree parents with characters approaching such contrast can be found if different species are crossed.

Another scientific contribution of species hybridization lies in its ability to assist other disciplines—for example, taxonomy. Data on species crossabilities and the fertility of hybrids can help toward understanding the relationships between species in large genera of great interest to foresters, such as the pines and spruces (*7, 41*).

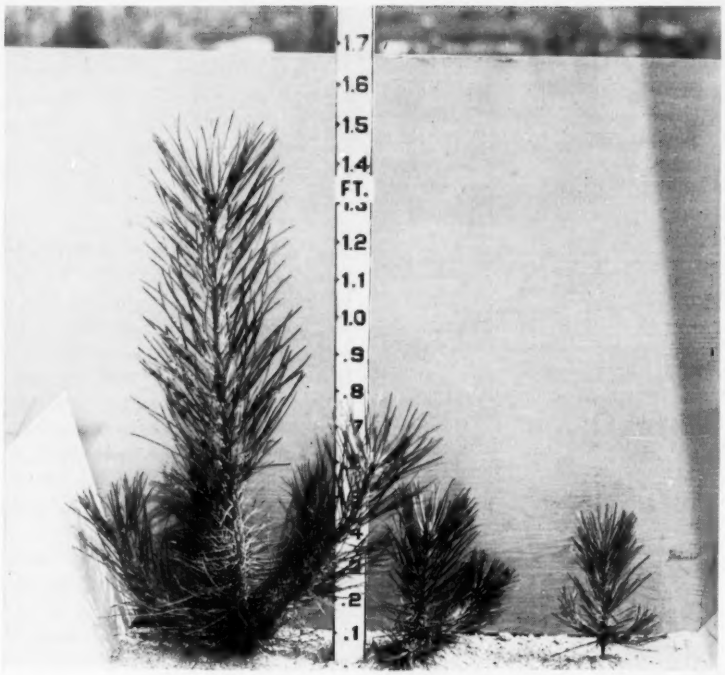


FIG. 1.—Left: *Pinus nigra* x *P. resinosa;* center: *Pinus nigra;* right: *Pinus resinosa.* Age 18 months. This is first successful cross involving Eastern and Western Hemisphere hard pines, and was made at the Institute of Forest Genetics, Placerville, California. *Photo by U. S. Forest Service*

Before we proceed, the term *hybridization* requires explanation. In the past it has often been used without indicating whether crosses within or between species were meant. For precision, it should be modified as: *interspecific hybridization* (crosses between members of different species), *intraspecific hybridization* (crosses between individuals within a species), *interracial hybridization* (crosses between members of populations within a species). In this review, *hybridization* will be used unmodified to mean interspecific hybridization.

In discussing hybridization as a means for genetic improvement of forest trees, one must compare it with other methods. Is it wise to dilute the research effort by adding to the as yet unexploited variability existing within each species still more variability derived from combining different species? Should not this effort rather be diverted to selecting the best variants we already have? A look at what improvements have been effected by hybridization of American forest trees may help us answer these questions.

In reviewing these accomplishments, we should bear in mind that organized tree improvement was started in this country by the Oxford Paper Company, in Maine, in 1924, just one pulpwood rotation ago. This review, because it ignores useful crosses that have been made but not yet published, undoubtedly

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underestimates the benefits already derived from hybridization.

### Hybrid Vigor vs. Combination of Parental Traits

The concept of hybrid vigor or heterosis is confusing and apt to be academic when applied to species crosses of forest trees. In simplest terms, hybrid vigor implies that the hybrid is more productive than either of its parents (Fig. 1). Since the habitats of the two parents are usually different, should we test in the respective environments of both parents or in an intermediate environment?

One of the earlier hybrids produced at the Institute of Forset Genetics at Placerville, California, was *Pinus monticola* x *monticola* x *P. strobus* (*33*, *35*). The seed parent is native to the high altitude forests of the Sierra Nevada above 5,000 ft. When this high altitude ecotype of western white pine is grown at the Institute of Forest Genetics, at an elevation of 2,700 ft., it makes rather slow height growth for at least 15 years. In the same environment, the pollen parent species, eastern white pine, makes height growth roughly comparable to that found in the forests to which it is native, and materially greater than that of the seed parent. The hybrids, however, exceed both parents. This is certainly a case of hybrid vigor at the Institute of Forest Genetics, but the hybrid is unable to survive in the Wisconsin habitat to which its pollen parent is native (*3*). This indicates that statements about hybrid vigor must be qualified and the origin of parent stocks and place of testing must be carefully specified. An almost parallel situation exists with the cross *Pinus contorta* var. *latifolia* × *P. banksiana* (*33*, *35*).

At any rate, hybrid vigor in the narrow sense is not all-important for forest tree species hybrids. What counts is whether the hybrid has a satisfactory growth rate and exhibits other qualities such as resistance to pests, to extremes of weather, etc., that make it preferable to both its parents in a particular locality. (Incidentally, in the case of pest resistance and the like, hybrids can often be evaluated before they have reached a harvestable stage). Accordingly, the growth rates of the hybrids in Table 1 are classified only with relation to the parent that the hybrid is a candidate to replace.

If a hybrid does not show hybrid vigor, it may yet offer an advantage due to a combination of the desirable properties of both parents. A hybrid in which these properties are combined in a completely intermediate fashion may be quite valuable in the distribution area of the less desirable parent or in an environment that only the less desirable parent will tolerate. An interesting example of this is the cross between pitch and loblolly pine (*Pinus rigida* x *P. taeda*). The seed parent has long been naturalized in Korea, where it shows its characteristic rough form, but grows well and is considered superior to the native *P. densiflora* Sieb. & Zucc. Loblolly pine, which excels pitch pine in form and growth rate does not survive in Korea except in a narrow belt along the southern coast. Hyun (*12*) has recently reported that the hybrid exceeds loblolly pine in cold resistance and pitch pine in form and growth rate, and he has launched an extensive program of producing the hybrid by mass controlled pollinations.

From the point of view of the genetic mechanism involved, the simplest case of a valuable combination hybrid is *Thuja plicata* x *T. standishii*. Soegaard (*37*) has shown that in this cross, resistance to the needle spot disease caused by *Keithia thujina* Durand. behaves as single factor dominant. Western redcedar is generally quite susceptible to this disease, particularly in the seedling stage; *T. standishii* is resistant. The hybrids are also resistant, and the progeny derived from backcrossing the hybrid to *T. plicata* shows a ratio of resistant to susceptible plants of 1:1, which is evidence of single gene inheritance and dominance.

A less simple case, but one of greater economic importance in the United States, is the hybrid between Jeffrey pine (*P. jeffreyi* Grev. & Balf.) and Coulter pine (*P. coulteri* D. Don). This hybrid, whose natural occurrence and botanical characteristics have been thoroughly described by Zobel (*42*), is, in general, intermediate between the two parent species in form and growth rate. However, under certain testing conditions, it illustrates the difficulty of distinguishing between heterotic and intermediate hybrids. Coulter pine is found south of San Francisco, mostly in the inner Coast Range of California, a region of rather high mean annual temperature. Jeffrey pine occurs throughout much of the natural range of Coulter pine, but in addition grows at higher altitudes and farther north in areas with generally lower temperatures. When Coulter pine is grown in these latter areas, it either fails to survive or grows only a little more rapidly than Jeffrey pine. In such areas, a hybrid is likely to grow faster than either parent, and it would be reasonable to claim hybrid vigor for this cross. Hybrid vigor apart, the Jeffrey x Coulter hybrid is valuable because it is highly resistant to the pine reproduction weevil, *Cylindrocopturus eatoni* Buch. which destroys seedlings and small saplings of ponderosa and Jeffrey pines (*26*). Even when the hybrid is back-crossed to Jeffrey pine, it yields a hybrid derivative quite closely resembling Jeffrey pine, is highly resistant to the pine reproduction weevil, and maintains a faster growth than Jeffrey pine (*6*). For these reasons, mass production of this hybrid has been inaugurated in California (*19*).

### Staying Power of Hybrids

As hybrids are often essentially new entities and inasmuch as forest trees must be relatively long-lived to have any value, the question is properly raised whether the early superiority of a particular hybrid will persist to harvest age (*4*). Naturally, no conclusive answer can be given until the hybrid in question is grown to rotation age. Nevertheless, evidence from natural hybrids found in the wild as well as

from artificial hybrids, gives us a large measure of confidence in the long-term performance of hybrids.

One of the first-discovered hybrids between Jeffrey and Coulter pines died in 1947, having attained a diameter of approximately 30 inches. Several natural hybrids between knobcone pine (*P. attenuata* Lemm.) and Monterey pine (*P. radiata* D. Don) have been discovered which are approximately 20 inches or larger in diameter. Moreover, artificial hybrids of this parentage growing in the arboretum of the Institute of Forest Genetics at Placerville have been harvested at diameters of approximately 24 inches. *Pinus sondereggeri* H. H. Chapm., one of the earliest described hybrids among American pines, is rather widely known throughout the range of the parent species, *Pinus taeda* and *P. palustris*. These hybrids are essentially as large and rapid growing as the parent species. The red flowering hybrid horsechestnut, (*Aesculus carnea*) is a hybrid of horticultural value which has the form of a forest tree and has thoroughly proven the staying power of hybrids. It is the result of crossing the American red buckeye (*A. pavia*) with the European horsechestnut. (*A. hippocastanum*) (*36*). Large specimens of this highly ornamental tree can be seen in many of the cities of the northeastern and northwestern United States.

There is a group of vegetatively propagated poplar hybrids, including crosses between several American and European species, which are collectively known as *Populus euramericana* Dode. To these hybrids, in the words of the Italian poplar expert, Piccarolo, "are due the successes of industrial poplar culture" (*31*). They have for a number of years been producing an important pulpwood crop in the Po valley of Italy, as well as elsewhere in southern and central Europe. A number of 27-year-old hybrids between *Abies concolor* (Gord. & Glend.) Lindl. and *Abies grandis* (Dougl.) Lindl. have been reported by Scheplitz, who found that their growth of these hybrids compared very favorably with that of *Abies grandis*, a preferred species for planting in Germany. The oak flora of California includes two well known and widely distributed hybrids, both of which attain large dimensions and grow at rates comparable to those of their parents. These are *Quercus ganderi* C. B. Wolf, a cross between *Q. agrifolia* Nee and *Q. kelloggii* Newb., and *Q. moreha* Kellogg, a cross between *Q. wislizenii* A. DC and *Q. kelloggii*. Numerous other oak hybrids have been listed by Palmer (*28*). These few instances, selected out of a list that might run to a hundred hybrids are grounds for confidence in the staying power of hybrids in general.

To the more searching question, "Do hybrids which, in youth, show superiority over one or both parents continue to do so?", we have as yet only a partial answer. It is in the affirmative for the knobcone x Monterey pine hybrid (27 years old) the Jeffrey x Coulter hybrid (15 years), the lodgepole x jack pine hybrid (15 years), and the ponderosa x Apache pine hybrid (11 years) (*6*). On the other hand, Bingham, Squillace, and Patton report that over the first three years of growth of the hybrid between *Pinus monticola* and *P. strobus*, the initial lead in height of the hybrid is gradually overtaken by *P. strobus* in tests at Spokane, Washington and Placerville, California (*3*).

## Choice of Parents

Foresters realize the importance of obtaining seed from the correct geographic seed source but they may not be aware that this is equally important in the selection of parents for hybridization. An example of aspen hybridization reported by van Vloten (*40*) shows clearly the effect of geographic origin. European aspens (*Populus tremula*) of Polish and Netherlands origins respectively, were crossed with the North American aspen *Populus tremuloides*. With the most vigorous European aspen cross as a standard or 100 percent, the cross of a Polish aspen with American aspen was rated as 114 percent whereas the Netherlands aspen crossed with American aspen was rated as 91 percent.

Barnes (*1*) has demonstrated a clear superiority in height and diameter growth of German x U.S. over Swedish x Canadian aspen hybrids (*Populus tremula* × *tremuloides*). Moreover, he found that the two hybrid populations differed significantly in average branch angle and that the hybrids of more northerly parentage started to flower earlier (6 years) than those of more southerly parentage. This study was conducted in northern Germany.

Duffield (*8*) reported that *Pinus monticola* of western Washington origin produces much faster growing hybrids when crossed with *P. strobus* than does than does *P. monticola* of Sierra Nevada origin. This test was conducted in the latitudinal range of the Sierra Nevada *P. monticola*, but almost 4,000 ft. lower in altitude (Fig. 2).

Within any given geographic race there is considerable variation in the growth and performance of individual trees. Similar variation results when different individuals within a single race are used in species crossing. The work of Bingham, Squillace and Patton consistently shows hybrid vigor in crosses between Idaho *Pinus monticola* and Wisconsin *P. strobus* (*3*). In addition, however, there are statistically significant differences in the growth rate of hybrids derived from different individual trees of *Pinus monticola* growing within the same watershed in north Idaho.

Testing of hybrids is related to and complicated by the provenance problem. Whereas we may accept it as a general principle that a native race of a species is likely to be the best performer in a particular locality, we have no such principle to guide us in the case of a hybrid one of whose parents is not native to the area in which the hybrid is to be used or tested. For example, if a hybrid between *Pinus monticola* and *P. strobus* is to be developed for use in north Idaho, it is very difficult to predict what local race of *Pinus strobus* will be

FIG. 2.—Left: *Pinus monticola* (California) x *P. griffithii;* right: *Pinus monticola* (Washington) x *P. griffithii.* Measuring stick 6 feet tall. Age 10 years. Eddy Arboretum of the Institute of Forest Genetics, Placerville, California.
*Photo by U. S. Forest Service*

most likely to produce a good hybrid for north Idaho conditions. Therefore, the experimenter is likely to have to test a large number of races of *Pinus strobus* as parents to be crossed with local *Pinus monticola.* Obviously the testing job is multiplied by the number of races of *Pinus strobus* involved.

Another difficulty is that tests are often conducted in areas distant from localities where the hybrids would normally be used. For example, many of the hybrids tested at the Institute of Forest Genetics at Placerville at an elevation of 2.700 ft. can reasonably be expected to be used for planting at elevations from 3,500 ft. to 5,000 ft. This is merely one example of the difficulty confronting many forest tree improvement programs. It is a problem likely to be solved as the increasing support for tree improvement work makes possible the development of more widespread and more appropriately located tests.

### The Utilization of Hybrids

Some of the first hybrids to be studied, both of plants and animals, possessed two characteristics which, if shared by forest tree hybrids in general, might make impractical or difficult the large-scale utilization of tree hybrids in artificial regeneration.

The first of these characteristics, hybrid sterility, is not nearly so common as was once supposed. It is interesting to note, in passing, that the early attempts of Klotsch (*17*) to make species hybrids in pines and oaks were motivated by the desire to produce sterile hybrids which would, because of their sterility, channel all of their photosynthetic activity into production of vegetative tissues. Most pine hybrids that have been at all carefully studied have proven to be highly fertile. The fertility of hybrids in other genera, particularly of broadleaves, varies quite widely.

If a hybrid with valuable characteristics proves to be completely sterile or infertile to a degree which would make its propagation from seed impractical, there still remain two possible courses. Most of the widely used poplar hybrids are readily reproduced from cuttings. In fact, one of the characteristics for which poplar hybrids are screened in the early stages of selection is the capacity to root readily and produce good plants from rooted cutings. With aspens, which are notoriously difficult to reproduce by cuttings, another expedient is available. Since aspens generally are dioecious—that is, have flowers of only one sex on a single tree—they lend themselves readily to production of hybrid seed in quantity by interplanting males of one species with females of the other. This procedure is being used effectively in northern Europe (*18*).

Another property of hybrids that is often supposed to stand in the way of their large-scale utilization, is the variability often found in their offspring. This would be a catastrophe in the production of most agricultural crops where breeding "tree to type" is highly desirable. However, Righter (*33*) has argued that forest tree breeders may well take an approach that differs basically from agricultural plant breeding. The relative impracticability of direct control of insects and diseases in the forest, and the time during which a forest crop is exposed to biotic and climatic hazards, make a genetically uniform forest quite unsafe. Syrach Larsen (*18*) has put the matter in language so plain that it bears quoting: "The difficulties are great; they are perhaps almost insurmountable, so long as we follow along the same lines that have been used in agriculture and horticulture. That is just what we should not do; *we should go our own way,* and the matter appears in a very different light."

In actual experience with pine hybrids it has been found that the $F_2$ progenies derived from mutual inter-pollination of stands of $F_1$ hybrids are often quite usable (*19*). This is a consequence of the fact that much silvicultural practice is based on the variation ordinarily found in forest stands. The variation may be due to differences between species in mixed stands, or may simply consist of grown differentiation in pure, evenaged stands. Whatever its magnitude, the variation can be accomodated, and is often deliberately sought. The variability of an $F_2$ or other advanced hybrid generation thus can be ex-

ploited not only by the breeder practicing genetic selection, but by the silviculturist managing a stand.

If the variability is too great for such a solution, use of the $F_1$ hybrid as with hybrid corn is indicated. The superiority of the corn hybrids is such that the growers gladly buy new seed each year. However, the forester is in a much better position with regard to the mechanism of seed production and vegetative propagation of superior types as has been very concisely stated by Syrach Larsen (*18*): "If the farmer discovers two plants which, when crossed, furnish fine progeny, then, because of the rapid succession of generations, he can take advantage of this to raise a true-to-seed variety. On the other hand, he has no opportunity of preserving the plants in order to repeat production of the fine progeny observed at the time of the first crossing, for the parent plants quickly die. It is quite otherwise with the forester. When he finds two trees which by mutual fertilization provide the desirable fine progeny, he has scored a success. He can at once proceed to make use of the two trees for future seed production. By grafting, budding or other form of vegetative propagation, he can not only preserve the two trees so discovered for as long as he likes; he can also supply himself with any desired number of new individuals with exactly the same tendency as 'the parents'."

In the thirties, a time when interest in polyploidy in plants was growing rapidly, it was thought that allopolyploid hybrids (that is hybrids which combine two sets of chromosomes from each parent and hence are true-breeding) would play an important role in securing the advantages of hybridization for forestry. Progress along these lines has been rather disappointing, but improvements in techniques may change the picture. The sole effectively true-breeding allopolyploid tree so far reported is *Aesculus carnea*, which is chiefly an ornamental.

Hyun (*12*) has made the most direct approach to practical utilization of forest tree hybrids. Although seed orchards for the production of the hybrid *Pinus rigida* $\times$ *P. taeda* have been established in those parts of Korea mild enough to grow *P. taeda*, Hyun has undertaken a large program of hand pollination in young stands of *P. rigida* to produce hybrid planting stock until the seed orchards come into production. This program effectively started in 1954, when 1,095 hand pollinations resulted in the production of 1,076 cones, 24,864 fertile seed and 16,739 seedlings. In 1955, the pollinations numbered 11,666, and in 1956 there were 23,438. Hyun calculates that *P. rigida* 1-1 transplants grown from wind pollinated seed cost $4 per thousand, under Korean conditions, whereas the hybrid trans-

TABLE 1.—PERFORMANCE OF SOME INTERSPECIFIC CROSSES INVOLVING AMERICAN TREE SPECIES

| Seed parent | Pollen parent | Outcome | Literature |
|---|---|---|---|
| *Aesculus hippocastanum L.* white-flowered tree | *A. pavia* L. red-flowered shrub | *A.* × *carnea* Red-flowered tree True breeding allopolyploid Common ornamental | *36* |
| *Betula verrucosa* Ehrh. | *B. papyrifera* Marsh. | Outgrows *B. verrucosa* in its range | *14* |
| *Betula pubescens* Ehrh. | *B. papyrifera* Marsh. | Outgrows *B. pubescens* in its range | *14* |
| *Castanea dentata* (Marsh.) Borkh. | *C. mollissima* Bl. | Hybrid susceptible to chestnut blight, but progeny of backeross to *C. mollissima* resistant | *2* |
| *Catalpa ovata* Don | *C. bignonioides* Walt. | *C. hybrida* Spaeth shows hybrid vigor | |
| *Cupressus macrocarpa* Hartw. | *Chamaecyparis nootkatensis* (D.Don) Spach | Outgrows *C. nootkatensis* Hardier than *C. macrocarpa* Good ornamental. | *27* |
| *Pinus attenuata* Lemm. | *P. radiata* Don. | *P. attenuradiata* outgrows *P. attenuata* to 27 yrs. More cold resistant than *P. radiata.* Form superior to *P. attenuata* and equal to *P. radiata.* | *38* |
| *Pinus contorta latifolia* Engelm. | *P. banksiana* Lamb. | Shows hybrid vigor to 14 years | *5,6,33* |
| *Pinus echinata* Mill. | *P. taeda* L. | Resists fusiform rust, which attacks *P. taeda* | *10* |
| *Pinus jeffreyi* Grev. & Balf. | *P. coulteri* D. Don also (*P. jeffreyi* x *coulteri*) | Outgrows *P. jeffreyi* More cold resistant than *P. coulteri.* Resists weevil which kills *P. jeffreyi* & *P. ponderosa* seedlings. | *19,26,33 35,42* |
| *Pinus monticola* Dougl. | *P. strobus* L. | Shows hybrid vigor | *3,35* |
| *Pinus palustris* Mill. | *P. elliottii* Engelm. | Good seedling height growth | *24* |
| *Pinus palustris* Mill. | *P. taeda* L. | *P. sondereggeri* Good seedling height growth. Form variable. | *24* |
| *Pinus peuce* Griseb. | *P. strobus* L. | | *9* |
| *Pinus ponderosa* Laws. | *P. engelmannii* Carr. (Apache pine) | Shows hybrid vigor Shows hybrid vigor | *6,34* |
| *Pinus rigida* Mill. | *P. taeda* L. | Outgrows *P. rigida* and has better form. More cold resistant than *P. taeda.* Better root system and survival than either parent. | *12,21,22* |
| *Pinus strobus* L. | *P. griffithii* McClell. | Outgrows P. *strobus* Resistant to blister rust, which kills *P. strobus* | *25,35* |
| *Pinus taeda* L. | *P. elliottii* Engelm. | Drought resistant | *43* |

TABLE 1.—PERFORMANCE OF SOME INTERSPECIFIC CROSSES INVOLVING AMERICAN TREE SPECIES (CONT'D)

| | | | |
|---|---|---|---|
| *Platanus orientalis* L. | *P. occidentalis* L. | *P. acerifolia* Willd. The most common ornamental sycamore. Widely used. | *33* |
| *Populus alba* L. | *P. grandidentata* Michx. | Combines good form of *P. grandidentata* with good rooting of *P. alba.* | *13,20,23* |
| *Populus* spp. European black poplar, species and hybrids | *Populus* spp. North American black poplar, species and hybrids | *P. euramericana* Dode Numerous clones. Dominate commercial poplar growing in Europe. | *30,31,39* |
| *Populus tremula* L. | *P.tremuloides* Michx. | Shows hybrid vigor | *15,40* |
| *Thuja plicata* Donn | *T. standishii* Carr. | Resistant to *Keithia thujina,* fungus which defoliates *T. plicata* | *37* |

plants grown from hand pollinated seed cost $5.52 per thousand. This relatively small increase in cost promises to be more than carried by the superiority of the hybrids over pitch pine. The report by Lorenz and Spaeth (*22*) that this hybrid excels *P. taeda* in cold hardiness and has reasonably good form in southern Illinois suggests that further work with this "all-American" hybrid might be appropriate along the northern limits of the range of *P. taeda* in the United States.

### Multi-species Hybridization

Multi-species hybridization has a fascination of the sort we may have indulged at the soda fountain in the days when the words good and complicated were synonymous. Hybrids with more than two species in their parentages are rather numerous, particularly in the poplars. The poplar hybrids of greatest commercial importance in Europe include *Populus deltoides* Marsh. in their pedigree. What other species, besides *P. nigra* L., they have in their parentage is highly uncertain. Actually, the problems of nomenclature in the poplars, which have been sketched by Pauley (*29*), are apparently the result of attempting to apply the rules of nomenclature for "wild" plants to a group which has passed over the threshold of domestication. Once this threshold is passed, species have little real meaning, and it becomes rather pointless to record the species pedigree of a particular cultivated variety in its name. The rules for nomenclature for cultivated plants recognize this.

Outside the genus Populus, it is hard to find multi-species tree hybrids that have yet proven their value. It seems likely, however, that the use of "bridge" species to bring together the genes of two non-crossable species may be an effective improvement procedure. For example Holst (*11*) has suggested that *Picea sitchensis* (Bong.) Carr. may be used to combine the genes of *P. abies* Karst. and *P. glauca* (Moench.) Voss to produce a form with the growth rate of Norway spruce and the weevil resistance of white spruce.

### Conclusion

From this very incomplete survey one might conclude that the benefits to American forestry which can, at present, be credited to hybridization are few and not too impressive. This is in general true. It is true also that America is blessed with a wealth of forest tree species, many of which have been exported to enrich the less varied floras of other parts of the world. Nevertheless, many of our economically important species are proving to be less than perfectly adapted to many ecological settings in which it would be advantageous to grow them. Furthermore, we have shown remarkable aptitude as importers of harmful forest insects and diseases. We have positive and increasing evidence that hybridization can, on occasion, increase both the adaptability and the pest-resistance of forest trees. There can be no doubt that it has an important place, together with other methods of tree improvement, in coping with these two problems.

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# Seed Orchards—Their Concept and Management

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CURRENT INTEREST in forest tree improvement poses the question: "How can large amounts of genetically superior seed be produced efficiently?" The seed orchard probably is the best method yet devised. This article attempts to bring together the most pertinent information on American seed orchards, their objectives, establishment, and care.

A seed orchard is a plantation of genetically superior trees, isolated to reduce pollination from genetically inferior outside sources, and intensively managed to produce frequent, abundant, easily harvested seed crops. It is established by setting out clones (as grafts or cuttings) or seedling progeny of trees selected for desired characteristics. Forest seed orchards are often established while genetic evaluation of the parent material is still underway. In such cases, components shown by progeny tests to be genetically undesirable will subsequently be removed from the orchards.

Care must be taken to distinguish seed orchards from seed production areas, which are good natural or planted stands from which the phenotypically inferior trees are removed and which are specially managed to increase seed production. As such stands are not originally established for production of genetically improved seed, the selection of the trees they contain is much less intensive than in the case of seed orchards, and their genetic worth is therefore usually problematical.

Seed orchards require special treatment and care and some specialized equipment. They must be considered in the same light as nut orchards, the products of which are not wood, but seeds. Intensive cultural methods will be necessary to insure continuous production of the highest quality seeds. The high value of crops from seed orchards will justify intensive cultural practices, but many persons feel that, with the development of special harvesting equipment, improved seed will be produced in seed orchards more economically than unimproved seed is now obtained by ordinary methods of collection.

## Development of the Seed Orchard Concept

Although special emphasis has recently been placed on them, the idea of seed orchards is not new. Many have been established in the United States, Europe and elsewhere. In 1928, Bates (*10*) recommended their use in this country,

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(*Photo by U. S. Forest Service*)

FIG. 1—The Georgia Forestry Commission's Arrowhead Seed Orchard, planned, eventually, to total 325 acres. Loblolly pine in foreground; slash pine beyond first break in rows. Spacing, 16 by 16 feet.

and Larsen (*59*) indicates that he and others recommended the use of "seed gardens" in Europe as early as 1934.

Most of the seed orchards now established in the United States are located in the South. However, interest in them is becoming more widespread in this country, and work is being undertaken in the Northeast, in the Lake States, and on the West Coast. Most of the seed orchards so far established in this country are of conifers, but interest is extending to certain of the hardwoods. Soon the term "seed orchard" should be familiar everywhere.

A number of papers have been published in this country on seed orchard establishment and management. Wang and Perry (*91*) report on the results of work commenced in 1953 in cooperation with forest industries in the South. Zobel (*102*) describes the initiation of seed orchards in east Texas by the Texas Forest Service in 1952, to produce loblolly pine (*Pinus taeda*) seed of drought-hardy strains, and also of strains with extremes of wood specific gravity. Hargreaves and Dorman (*34*) and Zak (*100*) describe the extensive seed orchards being established in Georgia, from which the Georgia Forestry Commission hopes to obtain the bulk of the huge pine seed requirements of that state (Fig. 1). Mergen and Pomeroy (*67*) discuss seed orchards for high gum yielding slash pines (*P. elliottii*) at Lake City, Florida. McKuseck (*62*) and Hitt and Brink (*43*) describe seed orchards designed to produce superior seed for Christmas tree production. In the Northeast, white pine (*P. strobus*) seed orchards now being established are expected to produce considerable quantities of seed by 1980. In the Northwest, Bingham et al. (*13*) have worked upon disease-resistant white pine (*P. monticola*) that will be used as a source of seed, and Duffield[2] and several others in the Northwest have grafted species such as Douglas-fir (*Pseudotsuga menzeisii*) and hemlock (*Tsuga heterophylla*) in the establishment of commercial seed orchards.

Many of the concepts of seed orchards in the United States have been developed from the earlier, intensive use of seed orchards in other countries. A review of what has been done, especially in the northern European countries, is most helpful to those contemplating setting up seed orchards in this country. Only a few of the more accessible and helpful papers will be mentioned here, although others are available in the literature.

One of the earliest and most active exponents of seed orchards is Larsen (*59*). Arnborg (*4*) clearly describes the seed orchard techniques used by the Swedish Cellulose Company for Scotch pine (*P. silvestris*) and Norway spruce (*Picea abies*). His booklet, written in English, describes tree selection, seed zones, orchard establishment, orchard layout and other pertinent points. In other papers, Arnborg (*5*) and Arnborg and Hadders (*7*) present good discussions of orchards of pine, spruce and birch, while Jensen (*51*) describes the establishment of pine, spruce, larch, birch, ash, oak, alder and walnut orchards. Bano (*8, 9*) discusses seed orchards in central Europe, while Bouvarel (*14*) describes methods used with conifers in France. Grull, et al. (*32*), Hoffmann (*46, 47*), Langner (*55*), Marquardt (*64*), Wettstein (*95*) and others describe seed orchard techniques in Europe.

Interest in work of this type has also been keen in Australia and South Africa. Florence and McWilliam's (*27*) work with American species in Australia gives much information of value in planning seed orchards in this country. The possibilities of seed orchards in South Africa are described by Griffith (*31*).

### Costs and Yields

Before setting up seed orchards, it is important to determine the initial costs involved and the yields that may be expected. Meaningful actual costs cannot be reported here since they will vary with species, location, and organization. But it is a fact that seed orchards are expensive to establish. The seriousness of this initial expense will be determined largely by the expected seed yields and the genetic improvement made possible by use of seed orchards. Certain of the economic considerations are discussed in detail by Perry and Wang (*75*).

Seed orchards in the United States are as yet too young to have produced seed in quantity. Fortunately, some indications of potential yields are available in records from other countries. Florence and McWilliam (*28*) state that stands of loblolly and slash pines yielded about forty-three and twenty-five pounds, respectively, of viable seed per acre per year at twenty years

[2]Personal communication.

of age. (See following sections for spacing and other details.) They postulate that, under Queensland conditions, each acre of a seed orchard should yield enough seed to plant two hundred acres each year. Larsen (*59*), from yields he obtained with some early grafts, concludes that for larch each acre of a fourteen-year-old seed orchard should produce enough seed for 360,000 plants. For Scotch pine he estimates that 200,000 plants can be produced per acre of seed orchard at ten years of age. Arnborg (*4*) estimates that an acre of Scotch pine will produce eighteen pounds of seed each year, while each hectare (2.5 acres) is calculated by Arnborg and Hadders (*6*) to produce approximately one million seedlings per year. Rohmeder (*79*) reports that Swedish foresters estimate each hectare will produce about 100 pounds of Scotch pine seed each year. He further predicts that eventually all the seed required for planting this species will be obtained from seed orchards. (Note the difference between Rohmeder's 40 and Arnborg's 18 pounds per acre, both for the same species.)

Many estimates have been made of expected yields from southern pine seed orchards. Wang and Perry (*91*) believe that one hundred million viable seeds can be obtained from 300 acres of slash pine or 200 acres of loblolly pine seed orchard (approximately 330,000 per acre from slash and 500,000 per acre from loblolly). For the same species Zak (*100*) estimates about twenty-one pounds of seed per acre of seed orchard per year. Other southern workers estimate that each acre of seed orchard will yield enough seed for 200,000 to 500,000 or more plantable seedlings per acre per year, depending on percentages of plantable stock and other factors. Species differences, fertilizers and cultivation, weather, insects, and method of harvesting, may all have important effects on yields. Yields may be higher than expected due to better filled cones, correct collection time, better handling, and correct extraction. A number of workers who have collected from seed production areas have found yields per bushel greatly increased. In the South, for example, expected yields of approximately one pound of seed per bushel in many cases rise to better than one and one-half pounds of seed per bushel of cones. Papers by Easley (*25*) and Zobel et al. (*104*) discuss this fully. Harkin (*35*) feels that careful seed handling can produce twice the yield per bushel that is commonly obtained, and the viability of such seed is well above average. Thus, estimates based on standard collection methods may be low; conversely, all the difficulties that may be encountered are not yet known, and annual collections on trees such as loblolly pine may well lessen yields through damage to yearling cones and to buds containing "flower" primordia.

### Seed Orchards for What?

Too often there is an attempt to establish a seed orchard before its purpose is clearly defined. No formula can be given here for trees that should be used to obtain scions, because choice will vary with purpose and with local conditions. In general, however, trees to be used in seed orchards should:

1. Have wood characteristics especially suitable for the lumber, pulpwood, or other end product desired.
2. Have silviculturally desirable morphological and physiological characters and growth rates.
3. Have desirable characteristics that are strongly controlled genetically, rather than chiefly governed by environmental conditions.
4. Be proven as to their genetic worth (or be under test).

Unfortunately, space does not permit a detailed discussion of the theory behind the seed orchard concept. As is discussed by Wright et al. (*98*) little is presently known of the inheritance pattern of many important tree characteristics. Although there is increasing evidence that seed orchards will bring improvement over methods of random seed collection now in practice, emphasis must be placed on point no. 4 above—that every seed orchard clone must be under genetic test and that only those individuals that prove to be genetically superior for the purpose in view should be retained.

Methods of progeny testing cannot be covered here. Although there is evidence (*7*, *57*) that the grafts give some indications of the potentialities of the mother tree, only testing of its control-pollinated progeny will give the final answer as to a tree's worth in the seed orchard.

In the establishment of seed orchards it is vital to use the geographic strains best suited to the regions in which seedlings will be grown. Racial variation has been repeatedly demonstrated and the separation of distinct races in a seed orchard is absolutely necessary. Marked differences are often found in the physiological response of seedlings within rather restricted local environments. For example, early tests by Zobel and Goddard (*103*) in Texas demonstrated the presence of pronounced differences in seedling survival among local strains of loblolly pine. European workers have long known the influence of geographic source of seed upon the survival and growth of tree species. Thus, selections for seed orchards must be made within the framework of the limitations imposed by the existence of geographic races.

### Location of Seed Orchards

Considerable care must be exercised to locate a seed orchard properly. The site must be biologically suitable for good seed production, should have the proper isolation, and should be so located that it can be easily and efficiently managed. Reestablishing a poorly located orchard in a more suitable place entails serious loss of time as well as great expense.

Seed orchards must be located on high-quality land in areas where climate will combine with soil to stimulate maximum production of sound seeds. Exposed locations subject to wind, snow, or ice damage should be avoided. The soil

should be fertile and have good internal drainage. Some fertile soils, such as muck soils, are unsuitable because they restrict operation of equipment on the area.

Most seed orchards are designed to permit either wind or hand pollination. To prevent contamination, the incidence of stray pollen from outside must be kept to a minimum. Commonly, seed orchards are isolated by surrounding them with land from which all trees capable of pollinating the species contained in the orchard are removed. Isolation strips of from 300 feet to more than a mile have been recommended by different workers (*101*). Wright (*96*, *97*), Colwell (*18*), and Buell (*15*) have investigated pollen dispersion from North American tree species. Wright recomends an isolation strip of 300 feet for pinyon pine (*P. edulis*); Colwell, somewhat less for Coulter pine (*P. coulteri*). For southern pines most workers suggest at least a 500-foot wide isolation strip.

Small seed orchards require disproportionately large isolation strips. Approximately forty acres are required for a square seed orchard of four acres if an isolation barrier of 500 feet is maintained. Efficient management, therefore, requires larger seed orchards, which have more favorable rations of isolation strip area to productive orchard area. Pollen frequency decreases exponentially with increasing distance from the source tree. Hence, larger seed orchards produce a greater percent of uncontaminated seed than small orchards. The difficulty of isolating orchards in general is increased by the usual location of the orchards within the natural ranges of the species, where isolation strips of the necessary widths are hard to obtain.

Since management of seed orchards will be an intensive agricultural operation, regular cultivation, fertilization, and spray applications will be required. Such intensive management dictates that the orchard be easily accessible so that expensive equipment and skilled labor can be used to maximum advantage.

Many pulp and paper companies in the South are establishing their own seed orchards with a ten to twenty-five million seedling goal for each orchard. Maximum efficiency would probably be obtained if the respective pulp and paper companies would band together to manage a series of large orchards at strategic points.

### Establishing the Seed Orchard

At present, most seed orchards are being established with grafts, though rooted cuttings, air layers, or seedlings could also be used.

Grafting scions should be obtained from healthy branch tips in the upper portion of the crown where shoot growth is most vigorous. With most species the current season's growth or one year wood is best. Scions should be cut several inches longer than needed to permit trimming to proper length by the grafter.

Collection of scions by climbing permits best choice of material, but is hard, hazardous work, and requires expensive climbing equipment for very tall trees. Beers (*11*) has described collection of scion material by rifle. This method often results in greater damage to the crown, because entire branches are usually shot down, but it saves much time and labor, and eliminates hazardous climbing.

Correct packing and shipping of scions is of vital importance. In Florida and neighboring states, Perry and Wang (*73*) place the scions in perforated plastic bags with a small amount of dry sphagnum moss for packing, and a ball of damp moss in one corner to maintain high humidity. The perforations permit the circulation of enough air to prevent a build-up of carbon-dioxide. Scions handled in this way have been shipped long distances and stored with a minimum of loss.

The Georgia Forestry Commission places the scions on a waterproof paper with moist sphagnum moss sprinkled among them, and rolls them into a package like a bale of seedlings, with the cut ends of the scions at the center and the tips of the needles exposed. Packages are refrigerated for transport and storage. If stored, bundles are placed in moist (not wet) sphagnum moss to insure high humidity. For transporting scions, the commission has equipped pickup trucks with insulated boxes, and uses ice to control the temperature.

In colder parts of the United States and in Canada excellent success has been achieved by collecting scions during the dormant season and storing these in a mixture of snow and sawdust or moss at below freezing temperatures. Holst (*49*) has had good results with scions kept at 0° F. from March until June. Hitt (*40*) recommends storage of scions below freezing and in snow. Storage below freezing has proven satisfactory only for dormant material; however, succulent scions may also be stored. The Georgia Forestry Commission has successfully grafted succulent slash and loblolly pine scions stored for more than four weeks at 34-38°F.

Techniques for grafting pine, spruce and Douglas-fir, the genera with which most large-scale seed orchard programs in North America are concerned, have been developed to the point that a year-round grafting program can be set up. If proper facilities are available, a small staff can continue grafting by changing methods as the season progresses. Lack of greenhouse space in the North and Upper South may, however, limit grafting to spring and summer. Limited availability of personnel for collecting scion material and for performing field work has led the Georgia Forestry Commission to concentrate on summer grafting of soft tissue. Perry, on the other hand, prefers to graft in Florida in winter on potted stocks, using a lathhouse for protection. In the Southeast, Zobel field grafts in late winter and early spring. In Canada, Holst et al. (*50*) have successfully grafted spruce and hard pine in the autumn; this schedule has permitted them to combine scion collection with cone collection.

Greenhouse grafting has been used to some extent in the South

but is more widely used farther north, as reported by Holst et al. (*50*), Hitt (*42*), Rudolph and Nienstaedt (*81*), and others. The general procedure is to bring potted seedlings into the greenhouse in mid-winter (usually January or early February) and force them into growth. As soon as new growth has begun and the seedlings are developing vigorously, grafts (usually side grafts) are made with dormant scions. One problem frequently encountered in greenhouse grafting is how to break the dormancy of the potted stocks. Various species may require a period of chilling or an adjustment of the light period in the greenhouse to break dormancy (*61, 70, 76*).

In Florida, Perry and Wang (*74*) have reported a high degree of success with shadehouse grafting of slash and loblolly pines on understocks grown one year in the nursery and one year in pots. The grafting season is from November to February. In the spring, after the grafts have taken and have hardened for a short period, they are planted in seed orchards. With proper care, there is little loss after outplanting.

Field grafting may be divided into two categories, hard and soft tissue grafting. Hard tissue grafting is usually done in late winter and early spring, using dormant scion material on seedling stocks shortly after they begin cambial activity. Zobel has had his best success from late February to early April. Holst (*49*) has expressed a rule of thumb which is "to graft tolerant conifers (such as spruce, fir, and white pine) at the time of first root elongation, and out-of-doors, where the roots are less handy as indicators, at the time bud swelling begins. Intolerant conifers such as the hard pines (red, jack, and Scotch pine) should be grafted when the rootstocks are elongating their shoots." He reports excellent takes of stored scion material on red pine in early June. Douglas-fir is considered an easy species to graft (*24*). Outdoor grafts of several kinds have given high percentages of takes. Brown has recently had excellent success with nursery grafting of loblolly and slash pines on dormant 1-0 stock *in situ*. Results were much better than greenhouse or lathhouse grafting on potted 1-0 stock.

*(Photo by Brunswick Pulp and Paper Co.)*

FIG. 2.—Excessive root curling of grafted southern pine, persisting for several years in the seed orchard, as result of keeping the understock too long in the pot.

The seedlings were grown in the nursery at wide spacing and were root-pruned between graft establishment and transplanting. Hitt[3] has found field grafting of red pine preferable to greenhouse grafting.

Loudon (*60*) gives a detailed description of soft tissue grafting as practiced in Europe during the late 18th and early 19th centuries. Cleft grafts of succulent material were made and protected with paper cones. The Georgia Forestry Commission has successfully cleft-grafted (and, less extensively, side-grafted) soft tissues of slash and loblolly pines on a large scale. Soft tissue grafting can begin in the field as soon as shoot elongation is sufficient to provide scions. It is somewhat more tedious than hard tissue grafting.

Many types of grafts can be used to establish seed orchards. For a detailed discussion of grafting techniques the reader is referred to the article by Nienstaedt et al. (*70*).

Humidity and temperature control are essential to prevent rapid transpiration from the scions. The grafts may be maintained in a controlled atmosphere as in a greenhouse or may be protected by individual shade and moisture controlling covers. Polyethylene bags are excellent for prevention of desiccation, but must be perforated here and there or be left untied to permit some ventilation, and must be shielded from direct sunlight to prevent excessive internal temperatures. They can be shaded effectively with Kraft bags or aluminum foil. Aluminum foil may be used alone by rolling the edges together to limit air movement and retain moisture.

The length of time during which greenhouse or lathhouse grafted stock must be retained in the pot may greatly influence choice of grafting method, particularly in the South. The roots of the rapidly growing southern pines usually become pot-bound if retained in the pot for two growing seasons (Fig. 2). The potted material requires considerable care in field establishment, and in dry years may require expensive irrigation until the roots extend beyond the original balls of potting soil. The Georgia Forestry Commission's experience indicates that in slash and loblolly pines the growth of the scion for the first season after outplanting in the field is very slow and that it takes about two years for potted grafts to develop the vigor attained by field grafts in one year. Kriebel[4] has observed that potted white pine in the greenhouse has shown similar stunting of scions during the first growing season after grafting and feels that this is partly a nutritional problem.

Little development of hardwood seed orchards has begun, but potentially helpful research in hardwood grafting is underway. Horticulturists have considerable experience in vegetatively propagating some hardwood species for ornamental

[3]Personal communication.

[4]Personal communication.

purposes. Hitt (*40*) has reported European grafting in aspen and oak. He also gives a grafting schedule for some forest trees used in Europe. Hardwoods included are of the genera Populus, Betula, Alnus and Quercus. Kriebel[5] has successfully field grafted sugar maple (*Acer saccharum*) using polyethylene and kraft bag covers.

Although perhaps because age was confounded with time of grafting and with individual grafter, graft survival showed no distinct trend over age of scion parent of loblolly or slash pines in the Georgia Forestry Commission's seed orchard program. There was a wide variation in the graftability of trees of the same age from the same stand, a phenomenon previously reported by most workers regardless of species. Among older trees, Zak (*99*) has found no correlation of graft take with age of scion tree in shortleaf pine. Brown has found that the graftability of individual trees varies widely between years.

Little is known about stock-scion relationships in forest tree species. Herrero (*39*) studied compatable and incompatable grafts using plum, pear and peach combinations. He found that incompatability may involve only abnormalities appearing at the graft union, or they may include this plus others, such as restricted vegetative growth, abnormal distribution of starch, premature degeneration of phloem, and signs of ill health in the leaves accompanied by early defoliation. Skinner (*86*) has reported that in the oaks the factor of durability is not correlated with initial take and that it may require several years for the stock and scion to get out of balance. Somewhat similar relationships have been reported in fruit trees (*77*, *78*). It has been observed that some incompatibility may be encountered with coniferous species. Death of grafted material, apparently from incompatibility between stock and scion, has been observed in Georgia seed orchards. In commercial slash pine seed orchards two clones have been found in which excellent initial graft takes are followed by death after several months.

At present most workers are using random nursery seedlings for their grafting stocks and therefore can expect some incompatability. Perry and Wang at the University of Florida are now engaged in investigations of scion-stock relationships and are experimenting with control-pollinated lines of root stocks.

One of the limiting factors in some grafting programs is the availability of scion material from individual parent trees. This is especially true in southern pines. The Tennessee Valley Authority (*89*) has reported preliminary results of work in budding loblolly pine. The parent shoot was cut back to force the development of buds from needle fascicles. These buds were then grafted. Early results are quite promising. If this technique proves satisfactory it will make possible many more propagules from an individual parent, especially a recent graft or cutting from a tested older parent, in a given period of time. Mirov (*69*) reports budded trees of slash pine and ponderosa pine alive after 11 years. Pauley (*71*) has budded a number of hardwood timber species.

Air-layering has been successful with young material under certain conditions (*44*, *65*) and offers an alternative to grafting for establishment of seed orchards. Research is under way on the air-layering of individual needle bundles, which again would make it possible to obtain many more propagules from an individual selection.

Rooting of cuttings for use in seed orchards has proved promising for some coniferous species, such as Monterey pine (*3*). It is also highly successful with some hardwoods such as certain species and hybrids of Populus. Enright (*26*) has recently reported the successful rooting of yellow-poplar cuttings.

### Spacing, Arrangement and Number of Clones in a Seed Orchard

Considerable thought has been given, by researchers such as Langner (*55*), Marquardt (*64*), and Klaehm (*54*), to arrangement of clones in seed orchards. Langner and Stern (*56*) describe a Fisher-lattice design for placing the plants in a seed orchard so that those of the same clone are not adjacent, yet are arranged randomly to permit statistical analysis of clonal differences. Larsen (*59*) describes a seed orchard arrangement for dioecious tree species in which superior pollen parents are intermingled with superior seed parents. In Florida, slash pine seed orchards have been established by assigning the row and column locations for a single clone with the aid of a table of random numbers. When two plants from the same clone were assigned locations with fewer than two intervening plants, the random number was rejected and a new number was drawn from the table.

Nearly all researchers agree that final spacings of clones in seed orchards should be between 20 by 20 and 30 by 30 feet. Spacings will vary with species, as for fruit orchards where narrow-crowned pear trees are usually planted at 18 to 22 feet, apples at 30 to 40 feet, and pecans at about 50 feet (*88*). Many seed orchards in northern latitudes have initial spacings of five meters by five meters (16 feet by 16 feet), with plans for removing every other plant to produce a final spacing of ten meters by ten meters (32 feet by 32 feet) (*4*). Schrook et al. (*84*) proposed the use of five meter by five meter spacings for German seed orchards. This spacing is for northern conifers which are characteristically slow growers and produce narrow crowns. At first, pollen production per tree will be low, so decreasing the initial distance between trees in a seed orchard should increase the amount of viable seed produced during the early years.

Species from southern latitudes tend to grow very rapidly and plantations at 20 by 20-foot spacing often close their crowns within 12 years. A minimum final spacing of 25 feet is generally recommended for seed orchards of these fast-growing species.

[5]Ibid.

Florence and McWilliam (*28*) studied the effect of tree spacing on seed production for slash pine, loblolly pine, and *Araucaria cunninghami*. Seed production was recorded over several years for stockings of 52 to 770 trees per acre. Approximately 120 trees per acre (19 feet by 19 feet) produced a maximum amount of seed per acre, while a spacing of 30 feet by 30 feet gave the maximum cone production per tree. These authors suggest a planting spacing of 24 feet by 24 feet for slash pine seed orchards.

There is a close relationship between the number of sound seeds per cone and the availability of pollen. Florence and McWilliam (*28*) found that number of germinable seeds per cone was doubled in years of heavy pollen production. Sarvas (*82*) made a detailed study of the relationship between the viability of the birch seed crop and the availability of pollen. Spacing will play a major role, especially during the early years of a seed orchard, in insuring an adequate pollen production. Staminate (male) flowers are not abundant in most young conifer seed orchards. Although the major emphasis in seed orchard management has been on obtaining abundant cones or female flowers, it must be recognized, especially at the wider spacings, that pollen shortage may also be a serious problem. Wright (*97*) urges moderate spacings to insure adequate pollination in young orchards of pine and spruce, which tend to produce little pollen at an early age.

Inter-pollination among grafts of the same clone is a real danger in orchards which contain few clones. All workers agree that several clones should be included in an orchard to minimize this danger, but there is no good experimental evidence as to the minimum number necessary for acceptably complete cross-pollination. Gustafsson (*33*), Arnborg (*4*), Langner (*55*) and others recommend the use of 10 to 50 clones per seed orchard. Lindquist[6] urges the use of a smaller number of clones (as few as nine) because of the limited supply of superior trees for any particular province. If too few clones are used, however, roguing of even a few clones that tests prove to be poor will leave serious gaps in the orchard. Most seed orchards in the southern United States include between 15 and 25 different clones in each acre.

[6]Personal communication.

### Culture and Maintenance of Seed Orchards

Little is known regarding optimal cultural methods for seed orchards. Much of present culture is based on experience with fruit or nut orchards.

In most parts of the nation, fruit orchards usually have a permanent sod cover or cover crops, with clean cultivation around the bases of the trees. Frequently a mulch of straw is spread under the crown of the tree to keep down weeds, maintain moisture, and build up organic matter. Cover crops help hold the soil in place and improve tilth. Leguminous cover crops add nitrogen to the soil. Experience indicates agricultural orchards with permanent sod covers produce the largest yields (*17, 36*). Certain cover crops, such as alfalfa, may draw water from the orchard during periods of water shortages; therefore, clean cultivation of fruit orchards is practiced in areas where moisture is critical. For reference, Gardner et al. (*29*, chapter 3) and Merrill (*68*) give good reviews of the whole soil management practices for fruit orchards.

Johnsson (*52*) and Dimpflmeier (*23*) discuss pruning and shaping of trees in seed orchards. Johnsson recommends pruning to maintain maximum heights at 25 to 30 feet to facilitate seed collection. He points out that pruning to develop a bush-like growth in hardwoods would be relatively simple. In conifers, however, the majority of the cones are found in the upper portion of the tree and severe pruning to limit height growth may seriously decrease seed production for spruce and other species. Kiellander (*53*) suggests that there is no danger in maintaining pine orchards with multiple stems, but recommends the maintenance of a strong central stem in larch and spruce. Data from intensive studies on the effect of pruning seed orchards are not yet available but observations on severely topped trees, such as those under power lines, indicate that the lower limbs of pines can provide heavy crops of cones. Grafting onto dwarfing stock is being tried experimentally and may provide a partial solution to the problem of maintaining trees at the proper height for easy seed collection.

### Flowering and Maximum Yields

Once established, the seed orchard must be managed to maintain maximum annual yields. This may be difficult because of inherent clonal variation and environmental influences that affect flower initiation and seed development.

The age at which seed orchards will come into commercial production and the period during which the grafted orchards will continue to produce are not generally known. Simak and Gustafsson (*85*) report good flowering on six and seven-year-old grafts. Bano (*8*) states that it is generally accepted that a seed plantation will yield at five to six years, though some grafts may yield the first year. Perry and Wang (*72*) consider that it will be about fifteen years after the date of establishment before large quantities of cones are produced, although they have obtained some cones from very young orchards. Others speak in terms of ten years. In Georgia, Zak (*99*) expects thirty cones per graft on loblolly pine and twenty cones per graft on slash pine after ten years. Occasionally, white pine and certain southern pines flower the first year or two, but cones produced so soon are few in number and sometimes have few viable seeds. Dimpflmeier (*23*), from some grafts made by H. Meyer 55 to 60 years ago, estimates that a seed orchard should yield seed for at least 60 years.

The seed orchard manager must understand the fundamentals of flower initiation and seed development. Horticulturists have long

been able to induce early and more abundant flowering in fruit trees, but only recently has this been tried on forest trees. Few studies have dealt with early differentiation of flower primordia in tree species and often cultural treatment to obtain greater seed yields has been little more than a scientific guess. While studying the induction of early flowering in apple trees, Sax (*83*) found that, to be effective, such techniques as bark inversions or girdling must be performed in June or early July of the year preceding the flower crop it is desired to induce. The greatest response was obtained from treatments made before or during the differentiation of flower bud primordia. Undoubtedly the same principles hold true for other tree species.

Several workers have studied the development of microsporangiate (pollen) and megasporangiate (seed) cones in numerous coniferous species; see Mergen and Koerting (*66*) for a review of the literature. The earliest recognized primordia of the seed cones in several genera, e.g., Pinus, Taxus and Pseudotsuga, were found during August or September, although inherent and environmental influences cause considerable variation even within one species. Mergen and Koerting (*66*) found that the initiation of male strobili in slash pine normally preceded that of the female by several weeks. Studies on flower initiation are vital in seed orchard management because of their value in determining the most effective time to apply fertilizer or other treatments to stimulate flowering.

In many species heavy seed crops usually occur periodically, regardless of any one environmental factor. Wenger (*94*), in studying the annual variation of cone production in loblolly pine at one location in North Carolina, obtained a good correlation between seed production and the May and June rainfall of the year of flower primordia formation—that is, two years prior to cone maturation. Whether this relationship is significant throughout an entire region remains to be seen, but available moisture during this period is probably a critical factor. Experience has shown, however, that certain vigorous trees with sufficient growing space fail to produce flowers even in years of heavy general flower production. These trees may then flower heavily in following seasons or in the so-called "off-years." There is no immediate or obvious explanation for such erratic flowering behavior.

### Flower Stimulation

Little is known about the flowering pattern to be expected in seed orchards. Will grafted scions from older trees that are cultivated, fertilized, and possibly irrigated produce moderate to heavy seed crops year after year, or will they continue to show a seeding periodicity?

Present knowledge about flower stimulation in horticulture, and to a lesser extent in forestry, indicates that certain cultural practices will encourage more abundant flower and seed production. Among these, fertilization appears to hold considerable promise. Although little information is presently available on the proper ratios or actual nutrient levels required for maximum yields, a number of workers have shown that soil amendments do significantly raise the level of seed production (*1, 12, 16, 21, 30, 93*). One of the more recent studies by Hoekstra and Mergen (*45*) indicates that fertilization not only increases the number of female flowers in 21-year-old slash pine, but also (if accompanied by stem injury or root pruning) induces earlier and more abundant flowering in 7-year-old trees which had not previously flowered.

Actual amounts and rates of fertilizer applications used by various workers on different sites cannot be accepted as blanket recommendations because for each seed orchard the level of available nutrients must be determined by frequent soil analyses. In an attempt to obtain badly needed fundamental information about nutrient levels, a number of studies such as the early one by the Texas Forest Service (*90*) have been initiated in established seed orchards. Although the Texas study has been in progress for four years, sufficient data are not yet available for critical evaluation of the response of grafted material to rather constant but different levels of N, P, and K. At present, however, the results of two fertilizer experiments at the University of Florida show a definite early stimulation of flower production on two-year-old grafts. The application of varying levels of nitrogen tripled cone production in one experiment. These studies must be continued for several years before optimum rates of fertilizer application can be determined. Presently, there is general agreement that moderate applications of commercial fertilizers can be used advantageously in keeping the individual trees healthy and vigorous, a necessity for maximum seed production.

Irrigation is frequently used to improve the quality and yield of fruit orchards. Droughts seriously curtail the growth activities of trees, and fruit set is frequently impaired. Several seed orchards are now established with provisions for irrigation. In drier areas irrigation may be necessary for maximum yields.

Practices such as stem strangulation, girdling, bark inversion, root pruning, and grafting on dwarfing understocks have been used by a number of workers, with varying degrees of success, to stimulate flowering (*37, 38, 41, 45, 48, 83*). In essence all of these practices, with the possible exception of root pruning, accomplish the same results, i.e., as demonstrated with radioactive tracers by Dickson and Samuels (*22*), they check the normal rapid phloem transport of organic food substances.

Holmes and Matthews (*48*), Hitt (*41*), Hoekstra and Mergen (*45*), and Mann and Russell (*63*) have found that, in several conifers, semicircular or spiral girdles stimulate flower and cone production more effectively than does strangulation by banding. Excellent results have been obtained by Sax (*83*) with bark inversions in fruit

trees; this method has not been successful on young white pine primarily due to early shrinkage and necrosis of the inverted bark segments.[7]

The use of dwarfing root stock has been very successful in horticultural practice and should not be overlooked in seed orchard management. It has not been tested sufficiently in forest tree species, however, to encourage its widespread use, although Heimburger (*38*) reported induction of early flowering by grafting juvenile suckers of aspen onto a dwarf variety of *Populus tremuloides*.

The possibility of stimulating more abundant flowering and fruiting by pruning has been suggested by Wareing (*92*). In one experiment the terminal buds on the lower branches of 12-year-old Scotch pine were removed and many of the proliferating short shoots bore male strobili the following season.

Although the above methods may be effective in inducing or stimulating abundant flowering, many are perhaps too injurious to use in seed orchards. Certain of the surgical techniques probably could be applied to hardwoods with less risk than to conifers, but they still must be performed with extreme care. Most American and European workers feel that moderate root pruning, accompanied by fertilization, is most likely to increase flowering with a minimum risk to the grafted material.

### Ailments of Seed Orchards

Every tree species has its insect enemies. These must be controlled through preventive spraying if seed orchards are to produce seed successfully.

For example, newly grafted southern pine seed orchards are particularly susceptible to attack by a beetle (*Pityopthorus pulcarius*), which bores in at the graft union and kills the scion (*74, 87*). Regular monthly sprays with benzene hexachloride or DDT will control these insects during the first year of growth. Spraying can be discontinued after the graft union is healed over.

Pales weevils can seriously injure grafted plants three or four feet tall, but can be controlled with aldrin.

Tipmoth (*Rhyacionia* spp.) attacks hinder the development of young plants. In some slash and loblolly pine seed orchards established at the University of Florida, DDT was found to be superior to benzene hexachloride for controlling tipmoths.

Red spider mites are an ever-present plague in seed orchards and are immune to chlorinated hydrocarbons like BHC and DDT, which kill lady-bugs and other natural enemies of the mites. Therefore, spraying with these compounds may induce heavy infestation of red spider. Malathion has proved effective in controlling red spiders. It is also effective for all the insects mentioned in this discussion, but unfortunately, it has a low residual effect. Regardless of residual effect, however, applications of insecticides must be more frequent during the periods of most active growth, to protect the newly formed tissues.

Once the trees reach cone-producing size, insects will take a heavy toll of the crop of cones. Numbers of species of cone and seed insects occur in most regions. Fortunately, methods for controlling such insects are being developed rapidly. Coyne (*19, 20*) and Allen and Coyne (*2*) report on identification of at least 16 species of insects attacking southern pine cones, and on the control of the most important ones with benzene hexachloride sprays applied twice to four times annually. These spray applications have been effective in reducing the losses from insects by 50 percent or more.

Birds have found that the neatly spaced trees of seed orchards provide ideal places to roost. Broken buds, bent leaders, and scorched foliage result. In Florida, one seed orchard owner was forced to build bird roosts beside each grafted plant to prevent extensive damage.

Deer often cause considerable trouble, as do goats and cattle. Livestock must be fenced out of young seed orchards.

Squirrel guards must be placed on trees of cone-bearing age in regions where these rodents destroy a large portion of the seed crop.

Fungus diseases can be dangerous. For example, cone rust (*Cronartium strobilinum*) destroys 18 percent or more of the southern pine seed crop (*80*). Prevention of fungus damage is difficult. Many fungicides injure pollen and hinder seed development and may thus defeat their own purpose.

[7] Personal communication.

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# Vegetative Propagation in Forest Genetics Research and Practice

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THOSE actively engaged in forest genetics research or the application of its results do not need to be persuaded of the importance of vegetative propagation in their work. This article is therefore confined mainly to the factors affecting the success of vegetative propagation and to details of the methods that seem to offer most promise with important American species, especially as described in the more recent literature. A few of the references cited may, however, be of additional interest as showing the scope, and in some instances the antiquity, of various vegetative propagation techniques (*5, 38, 84, 105, 116, 127, 144, 145, 146, 160*).

## Grafting

Three basic graft-types are recognized, depending on the stock upon which the scion is implanted. In *autoplastic grafting*, the scion and stock are of the same genotype; in *homoplastic* grafting, they are of the same species; in *heteroplastic* grafting the scion is placed on an individual belonging to a different species, genus, or even family (*100, 103*).

### Physiological and Anatomical Bases for Grafting

*Union formation.* — Grafting is based on the ability of the stock and scion to develop new cells along their cut surfaces and unite to form a union. Depending on the plant, different patterns of meristematic activity are possible. Wound callus production is not limited to the primary meristems; parenchymatous cells of the cortex, the phloem, rays, and the pith can become secondary meristems (*78, 101, 140*). Cambium need not be involved, as apparently any living cell without secondary walls can form callus (*12*). After a graft has been made, the nearest intact parenchyma cells of both stock and scion enlarge rapidly and produce many cells, which collectively are called callus. Although the cut surfaces of both stock and scion form callus tissue, more callus is produced by the stock because it suffers less from the shock of grafting (*35, 101*). The sequence of the various anatomical changes taking place during the knitting of a union varies considerably from species to species, but the steps involved are basically the same, namely: (1) a contact layer is formed, (2) callus tissue is generated, (3) the contact layer is eliminated and the callus starts to differentiate, (4) the vascular elements connect, and (5) a common cambium is formed. Therefore, it is important to have smooth and closely fitting graft surfaces to facilitate the formation of a union. As much cambium as possible of the stock and scion should be matched, and the two graft partners should be tied firmly together (*95*).

The union formation is very rapid. Side-slit grafts of slash pine (*Pinus elliottii*) using seedling stock under indoor conditions have formed an almost complete union in 6 weeks (*101*). Bud grafts unite even faster (*12*).

*Compatibility.*—Little is known regarding the intrinsic factors in the plants that enhance or retard the formation of a union, but hormones undoubtedly are important. Similarly inherent factors—either chemical or anatomical — are the causes of incompatibility between stock and scion, i.e., graft failure or delay or partial inhibition of union formation. Knowledge about compatibility of forest trees is a matter of major concern, but only a little information is available. In the genus Quercus, N. T. Mirov and W. C. Cumming found that the cork oak, *Q. suber,* an evergreen oak of Mediterranean origin, was incompatible with the common California live oak, *Q. agrifolia,* but was entirely successful on the canyon live oak, *Q. chrysolepsis* (50). The compatibility in interspecific grafting of Populus shows a definite sequence of genetic affinity (*11, 56*). This sequence corresponds to the interspecific crossability patterns described by Wettstein (*174*), and Stout and Schreiner (*158*). An experiment by S. S. Pauley has demonstrated that the compatibility in root grafting of trembling aspen, *P. tremuloides,* on inter- and intraspecific hybrids involving balsam poplar, *P. balsamifera,* and cottonwood, *P. deltoides,* is a clonal characteristic.

In horticulture graft failure is a serious problem, and dwarfing resulting from incompatibility has been used to induce early flowering in certain instances (*23, 114, 132, 135, 136, 167*). Claims that seedlings can be induced to flower are not generally accepted (*147*). The dwarfing effect as such has also found wide application in orchards and gardens. Because of its importance, many methods of evaluating stock/scion compatibility have been tried. Those listed by Evans and Hilton (*40*) for apple grafts were useful where a wide range of compatibility was involved, but failed to detect apparent minor differences. Graft failures in forest tree seed orchards must be anticipated, and research should be conducted on the possible wide application of dwarfing techniques in such orchards. Basic research on the intrinsic factors controlling grafting success is also needed.

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### Stock and Scion Activity and Grafting Success

The old horticultural manuals stressed the importance of the growth activity of the scion and the stock at the time of grafting (*94*). Most often dormant conifer scions are used, and the stock plant is forced into an active stage of growth before it is grafted. For the broadleaved species either dormant or active stock can be used with dormant scions. Forcing of the stock plant is done in heated greenhouses (*87, 104*). In field grafting, where the activity of the stock cannot be controlled closely, the practice has been to collect the scions during the late fall or early winter, and store them in plastic bags in a refrigerator or a deep-freezer, or bury them in snow and ice until used (*65, 157*). Recently, however, successful fall grafting of red and white pines (*Pinus resinosa* and *P. strobus*, respectively) and spruce has been reported (*65, 67, 120*).[2] The effect of the amount of rootstock activity on the success of fall grating of spruce was negligible (*120*).

Soft-tissue grafting of pines was described in great detail a full century ago (*94*), but has been used on only a limited scale in forest tree improvement work (*76, 102*). However, all the trials reported so far have yielded good results. This method has obvious advantages as it allows extension of the grafting period over a considerable length of time, and a large percentage of strong unions are obtained because the cells of both stock and scion are not lignified and are in an active stage of differentiation at the time of grafting. With succulent tissue, heteroplastic grafts can also be made (*103*). Successful soft-tissue grafting of beech and maple has been described by Muckadell (*116*). The big drawback to the method is the perishable nature of the scions. This may limit the general application of the method.

### Environmental Factors Influencing Grafting

Unless a root graft or a cleft or splice graft close to the base of the stock is used, the stock plant does not suffer a severe shock at the time of grafting. The scion, however, has to sustain life as an independent plant part without the benefit of a root system for a period of time, and should be placed under the optimum environmental condition for meristematic activities so that a union can be formed without any delay (*15, 168*). Scions can be protected from desiccation during this period by keeping them in a saturated atmosphere or by placing their bases in water. When grafts are kept in a sweatbox in either the greenhouse or the field, a moderately humid atmosphere should be maintained until the union forms, and then the boxes should be partially opened. Wide temperature fluctuations during the first weeks after grafting should be avoided. The night, or low temperature, should not go below 60° F., while the maximum, or day temperature, should not go above 75° (*10, 62, 104, 114, 175*).

Effects of daylength on grafting success have been reported in a few cases. Dorsman and Ravensberg (*31*) got quicker and better unification of Betula grafts using additional lights at night. Kleinschmit (*80*) obtained a higher percent "take" with pine, using a 17-hour photoperiod rather than shorter ones.

The control of the environment becomes particularly important in fall grafting indoors, because prolonged lack of chilling may be detrimental to the grafts (*67*). The following schedule has been suggested for fall grafting of spruce: After grafting the grafts are kept in the greenhouse with a 20-hour photoperiod for 4 weeks and then on a short-day regime for 2 weeks. They should then be chilled for 8 weeks at about 40°F., and finally returned to long-day conditions in the greenhouse for renewed growth (*120*).

*Greenhouses.*—A well-equipped greenhouse constructed of either glass or plastic usually offers good controlled conditions for grafting. Satisfactory results have been obtained with a number of forest trees under rather different conditions. They include the grafting of pines and hardwood species in the Northeastern States;[3] the propagation of white pines for blister rust investigations in the Lake States, New York, Quebec, and British Columbia (*57, 60, 74, 133*); the grafting of southern pines in Tennessee, Georgia, Florida, and Texas (*15, 104, 176, 181*); and the grafting of spruces and northern hard pines in Canada (*67*).

The control of the greenhouse climate has been the subject of a series of studies (*13, 64, 88, 89, 117, 118, 173*). In the northern climate, the heated greenhouse is essential for grafting during the fall, winter, and early spring with dormant scions. In the South, on the other hand, air conditioning is essential during much of the year.

Humidification and misting systems, sweatboxes, etc., are used to control the relative humidity. "Plunging," i.e., covering the grafts in a bed of sphagnum to a point just above the graft union, gives good results.

It is best to use well-established stock plants for dormant greenhouse grafting; therefore, they are commonly potted in the spring for use the following fall and winter. One method of grafting white pine in Wisconsin is to place 2-year-old potted transplants in a warm greenhouse in early January with continuous light for the first 48 hours. When new growth begins to appear on these stock plants, scions are collected and the grafts made (*134*). In Canada about 6 weeks in the greenhouse are needed to bring the rootstocks into a stage suitable for grafting. Rootstocks taken in on January 15 will be ready about March 1 (*67*). Norway maple (*Acer plantanoides*) taken into the greenhouse in late November before chilling requirements had been fulfilled were only partly active by middle February. Those taken in late December flushed in 3 weeks; by February only 13 days

[2] Also reported by Dr. C. Heimburger, Southern Research Station, Maple, Ont., in personal correspondence with Wang.

[3] Reported by A. G. Johnson, University of Minnesota, in personal correspondence with Wang.

were needed for the plants to resume growth.[4]

*Lath houses.*—A lath house is a valuable part of a propagation unit. The greenhouse grafts are hardened-off there before they are field planted. In some areas, for example in northern Florida where the minimum temperatures drop below freezing for only a few days annually, grafting during the winter does not have to be done in a greenhouse, but can be done in a lath house. The newly grafted plants are kept under the shade for 6 to 8 weeks before they are outplanted (*168*).

Lath houses are easily constructed of treated lumber, posts, and snowfencing. A house, 60 by 32 feet, of this type erected at the Northern Institute of Forest Genetics in Wisconsin cost approximately $800. Snowfencing lasts only a relatively short time, and frequent repairs or replacements are usually needed after a few years. Satisfactory results with a shade house, built with plastic saran cloth over a rigid frame, have been experienced by the Arnold Arboretum and by users in the South. The cloth has several advantages: It gives long service and an even shade and is available in a variety of densities. In the North, the cloth must be taken down during the winter as it cannot support heavy accumulations of snow. Aluminum lath houses also are available.

*Temporary protection of field grafts.*—A number of temporary covers have been developed for the protection of field grafts. For many years Heimburger[5] has successfully grafted pine, using double bagging with a pliofilm and a kraft paper bag. Holst (*65*) has tried four different kinds of temporary covers in the grafting of red pine on Scotch pine, *Pinus sylvestris*, in the plantation during mid-June. The double protection of a polyethylene bag plus a kraft paper bag gave the best result. This bag combination has also been used successfully with soft pine species and hybrids and is generally used with the southern pines (*128, 176, 177*). However, because of the high temperatures in the South, the bags must be removed gradually to prevent damage from sudden exposure.

### Aftercare of Grafted Plants

Pruning of the stock plant is necessary after grafting to favor growth of the scion. Usually it is not done until a successful graft union is evident, but Holst et al. (*67*) recommend partial pruning of the rootstock at the time of grafting to reduce the rate of callus formation and diameter growth of the stock. If this is not done, the scion may be "walled off" by callus or strangled. The part of the stock that is in direct competition with the scion is pruned first. Side branches are removed later in a series of operations without seriously weakening the grafted plants. At the same time the grafting band is examined and cut loose if necessary to avoid strangulation. Special rapidly deteriorating rubber bands can also be used to avoid the latter problem.

Smith and Mergen (*151*) reported bark beetle attacks on slash pine grafts. Holst (*65*) lost many red pine grafts as a result of *Pissodes strobi* activity. Nienstaedt observed heavy beetle damage on topworked chestnut, and spruce mite damage on fall-grafted spruce in the greenhouse.[6] Damage from fungi is also common, especially in sweatboxes and under bag covers. Spraying with insecticides and fungicides is therefore essential (*169*). A light but thorough spray with a mixture of fungicide and insecticide should be applied immediately after the grafts are waxed and before bagging. A second spraying should be done approximately 6 to 8 weeks after grafting or when the bags are removed. Additional spraying may be needed later.

Light surface dressings with a balanced commercial fertilizer may improve the vigor of both field and greenhouse grafts. A liquid foliage fertilizer has been applied to grafted pines—especially pot-bound trees—to stimulate growth.[7]

Many coniferous species, including pines and particularly spruces, have a spreading growth habit for several years after grafting and must be supported until growth is upright. Similarly bud grafts and weak grafts, such as the splice graft, should be staked until the grafts are well established. The young grafts may be pruned to develop a desirable growth form.

### Grafting Methods

Many grafting methods have been tried and are described in the literature. Some of them are highly involved and can be performed only by their originators or the most skillful professionals. However, foresters should not panic—simple grafting methods are best as long as the stock and scion fit intimately and a strong union is ultimately developed. A number of the more important types are described and illustrated in this section. Table 1 lists their use by species groups.

*Approach grafting.*—In this method the scion is supported by its own root until it is completely united with the stock, not until then is it severed from the parent plant. It is used in grafting birches and other difficult species. Natural approach grafts are not uncommon (*6, 16, 47*).

Inarching differs from the standard approach method in that the "scion" is much smaller than the "stock" and is decapitated before it is inserted into the stock. It is used in bypassing diseased stem sections on partially resistant species and hybrids of Castanea (*62, 121*).

Another modification is the *bottle graft* in which the severed end of the scion is kept in a bottle of water until unification. This method has been used for the production of seed on cut branches of birch, elm,

[4] Information collected by senior author and on file at Lake States Forest Experiment Station.

[5] Unpublished information; see footnote 2.

[6] Unpublished information on file at Lake States Forest Experiment Station. The data on chestnut were collected at the Connecticut Agricultural Experiment Station in New Haven, Conn.

[7] Price, T. E. Unpublished data on file at the School of Forestry, University of Florida, Gainesville, Fla.

alder, aspen, and poplars (*77*). It is commonly used for the grafting of difficult species and has been tried in the grafting of southern pine and eastern white pine (*15, 104*).

*Detached scion grafting.*—The methods in this group fall into three main categories: (1) scion grafting on established plants, (2) bud grafting, and (3) root grafting. The first category includes the methods commonly used in the grafting of forest trees.

The *cleft graft* (Fig. 1A) and the *saddle graft*, which is an inverted cleft graft, are the methods most often used in soft-tissue grafts. Initially they do not form strong unions, but excellent knitting is soon accomplished with soft tissues.

The *splice graft* (Fig. 1B) is the simplest of all scion-grafting methods. It is best adapted for scion and stock of approximately equal diameter. It is a weak graft and should be used only with material that unites easily. Hardwoods are often grafted with this method.

The *whip-and-tongue graft* (Fig. 1C) is a modification of the splice graft. The resulting union, however, is stronger and, as it is simple to make, it is one of the most common hardwood grafting methods. It is also used on pine.

The *veneer graft* (Figs. 1D and 2) is the method most commonly used for conifer grafting. The *side graft* and the *pocket* (side-slit) *graft* are modifications of the veneer graft; they can all be used for hardwood grafting when the scion is smaller than the stock.

The *cleft crown graft* (Fig. 1E) and the *veneer crown graft* (Fig. 1F) are used for topworking, i.e., grafting into the crown of well-established trees. Seed orchards can be established using these grafting methods in plantations with trees 1 to 2½ inches in diameter at breast height. The grafts are made on the cut stub at breast height.

The *bud graft* (Fig. 1G) is used extensively in the propagation of citrus, peach, and other horticultural plants. Budding probably is the most rapid and inexpensive method of grafting. A good propagator may put in from 1,500 to 2,000 peach buds in 1 day and keep 2 or 3 men busy tying (*1*). The use of budded transplants as a means of introducing genetically superior trees into the forest has been suggested (*86*). Interspecific bud grafting of sugar maple (*Acer saccharum*) on red maple (*A. rubrum*) and of yellow birch (*Betula alleghaniensis*) on gray birch (*B. populifolia*) has also been mentioned as a possible inexpensive method of improving stands of low quality (*126*). So far, however, bud grafting has been used only experimentally in the United States. In Denmark it is the standard method with ash (*85*) and in Sweden it is used on birch, ash, elm, and aspen (*77*). Oak has been grafted only on an experimental scale (*85*), and the results with chestnut have been poor.[8]

TABLE 1.—SUCCESSFUL METHODS OF GRAFTING VARIOUS GROUPS OF TREE SPECIES

| Plant groups | Successful grafting methods reported | Literature references |
|---|---|---|
| White pines | Cleft graft | (*15, 76, 112, 125*) |
| | Side graft | (*2, 15*) |
| | Side graft with tongue | (*112*) |
| | Veneer graft | (*10, 134*) |
| | Bud graft | (*112*) |
| | Bottle graft | (*10*) |
| | Inarching | (*112*) |
| Southern hard pines | Cleft | (*15, 53, 105, 112, 128, 169, 181*) |
| | Side graft | (*15, 53, 105, 177, 181*) |
| | Veneer graft | (*177*) |
| | Soft-tissue graft | (*102, 177*) |
| | Stem approach graft | (*71*) |
| | Root approach graft | (*71*) |
| | Bottle graft | (*15, 53, 105, 177, 181*) |
| | Bark patch bud graft | (*71, 112*) |
| Northern hard pines | Cleft graft | (*112*) |
| | Side graft with tongue | (*112*) |
| | Veneer graft | (*65, 67*) |
| | Splice graft | (*112*) |
| | Shield bud graft | (*112*) |
| | Shield patch bud graft | (*112*) |
| | Inarching | (*112*) |
| Spruces | Veneer graft | (*66, 67, 138*) |
| | Pocket graft | (*67*) |
| | Inarching | (*112*) |
| Hardwoods | Cleft graft | (*24, 50*) |
| | Splice graft | (*24, 52*) |
| | Veneer crown graft | (*52*) |
| | Slot bark graft | (*24*) |
| | Inarching | (*50*) |
| | Bark graft | (*52*) |
| | Bridge graft | (*24*) |
| | Bud graft | (*24, 126*) |
| | Plate bud graft | (*24*) |
| | Patch bud graft | (*180*) |
| | Root graft | (*24*) |

The *root graft* is another method that has been used extensively in horticulture but very seldom in forest tree breeding. Scions are grafted to detached root pieces, usually during the dormant season. They are either planted directly in the greenhouse or placed in cold storage until they can be field planted. Sometimes inverted root pieces are grafted into cuttings of hard-to-root species such as aspen as a nurse root until the cuttings form their own root systems.

## Rooting of Cuttings and Air Layers

Cuttage, or rooting, is an asexual propagation method whereby roots are induced to form on severed parts of a plant such as stems, leaves, and root pieces (Fig. 3). In layerage the plant part, usually a branch, is left attached to the parent plant and severed only after roots have formed. In airlayering (Fig. 4), the stem is girdled above ground and the zone of root produc-

[8] Unpublished information; see footnote 6.

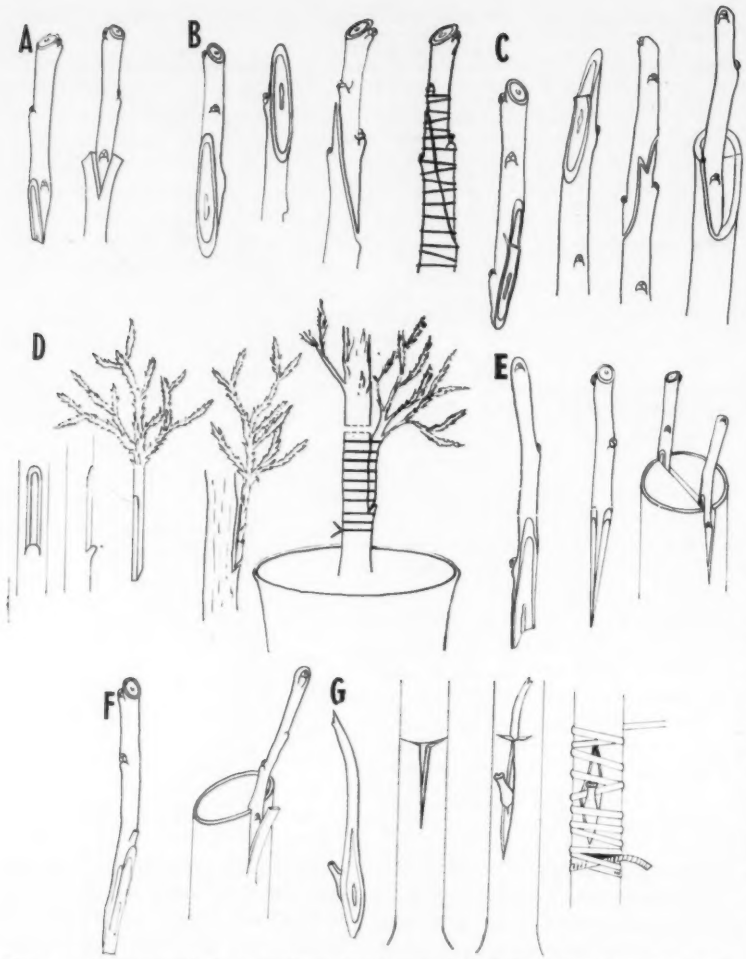


FIG. 1. —Common methods of grafting forest trees. (A) cleft graft, (B) splice graft, (C) whip-and-tongue graft, (D) veneer graft, (E) cleft crown graft, (F) veneer crown graft, and (G) bud graft. (Drawing adapted from The Grafter's Handbook by R. J. Garner, published by Faber and Faber, Ltd.)

tion is encased in a ball of moist sphagnum moss.

Trees of many forest species, and older specimens of many more, are difficult to root. The key to success is a more thorough understanding of the physiological processes involved.

### Physiology of Root Formation

*Water relations.*—When the cutting is severed from the parent plant its supply of water and solutes is interrupted. A water deficit is created within the tissues if transpiration continues. Water stresses within the cutting hinder metabolic activity and cell regeneration and, consequently, the initiation of roots.

Water loss may be minimized by controlling the environment of the cutting or by reducing the transpirational surface by shearing or deep planting. Deep planting also increases the water-absorptive surface in the medium and allows greater water intake by the cutting.

Satoo and Hukuhara (*142*) studied the transpiration rates in Pinus, Cryptomeria, and Euonymus and found that they were extraordinarily high the day after planting as compared with those of seedlings or rooted cuttings. Thereafter they decreased gradually until they leveled off at a rate lower than that of seedlings or rooted cuttings. When callus formed, transpiration began to increase, and further rapid increase took place when roots were formed. This may indicate that the first few days after cuttings are planted are the most critical with regard to transpiration losses.

Much of the greater success in rooting the air-layered shoot, in contrast to the severed cutting, can be attributed to the uninterrupted flow of water and solutes through the xylem still connecting the air layer with the parent plant. Transpiration is also unimpeded, but whether this process is beneficial to the air-layered shoot is controversial. The severed cutting, in contrast, is allowed to transpire little, if any, and water renewal in the tissues is slow.

*Food supply.*—The relative amounts and the balance of foods in the cutting and air layer are important factors affecting root initiation and growth. The supply of carbohydrates and proteins must be adequate to satisfy energy and tissue-building requirements. A high C/N ratio has been found necessary for rapid root formation. Cuttings low in carbohydrates and high in nitrogenous foods root poorly. However, nitrogen may become so low that rooting will be poor in spite of a high carbohydrate content (*95*).

As pointed out by Mahlstede and Haber (*95*), the nutritional status of the cutting depends upon the time of the year it is taken and the vigor of the parent plant. Softwood cuttings severed early in the growing season will contain relatively small quantities of stored foods and must satisfy their needs by photosynthesis while in the cutting bed. One of the major benefits of current misting practices is that cuttings can be fully exposed to light, even full sunlight, for maximum photosynthesis without injury from excessive heat and moisture loss. The light quality which is optimum for photosynthesis will probably also give the best rooting results.

Deciduous cuttings, which depend wholly upon the stored foods until leaves develop, will root best if they are taken when stored food

FIG 2.—Vencer graft of spruce ready for tying.
*Photo from Petawawa Forest Experiment Station, Chalk River, Ont.*

FIG. 3.—Needle fascicles from 1-year-old shortleaf pine seedlings rooted 4 months after planting. Center fascicle produced shoot from its base after 4 additional months.
*Photo from U.S. Forest Service, Southeastern Forest Experiment Station*

is highest in the parent tree. Early winter may be best but the specific time will depend upon the species and the climatic zone. This requirement may not be critical for evergreen cuttings which, when placed under suitable environmental conditions, will resume photosynthetic activity.

Many attempts have been made to augment stored food in cuttings by treatment with sugars and nitrogenous substances prior to or after planting (*106, 124*). Few, if any, have shown improvement in rooting. Most trials have given extremely erratic results, usually because fungal infection was severe.

In the air-layered shoot, photosynthesis proceeds at a normal rate, resulting in the accumulation of large quantities of food in the tissues giving rise to roots. As a consequence, root initiation and growth are rapid and roots produced are heavy and vigorous. Often species and age classes difficult to propagate by cuttings are successfully multiplied by air layers.

*Hormones.*—Plant hormones, also known as auxins, are organic compounds synthesized by the plant; in minute quantities they exert a regulatory effect upon specific physiological processes in various tissues. Several have been isolated from plant parts but little is known of their formation and the manner in which they function. IAA (indoleacetic acid), believed to be the most important growth hormone in plants (*110*), has been shown to be effective in stimulating root formation. A much greater concentration is needed for this process than for root elongation. A number of synthetic homologs of this auxin, such as IBA (indolebutyric acid) and NAA (naphthaleneacetic acid) display even greater root-forming properties.

The highest concentration of auxins is found in the shoot apex and in young expanding leaves, but these substances are rapidly translocated towards the base (*90*). One may, therefore, assume that they accumulate at the base of the severed cutting or air layer and stimulate root formation. The fact that leaves and buds increase root formation may be due in part to their auxin production. In part it may be a nutritional effect.

Seasonal variation in the hormone concentration has been demonstrated by many writers (*90*), and Lindemann (*92*) has suggested that differential rooting responses during the year parallel this fluctuation in the hormone amount.

*Age.*—Physiological age of the parent tree is one of the most important factors affecting the rootability of cuttings and air layers and is the factor which until now has made the rooting of cuttings impractical in tree-breeding work except in the cases of a few easy rooters. Tree breeders almost invariably want to root older trees with well-established traits, but very low rooting capacity. The young trees of unknown merit are usually easy to root.

The literature cites many examples of this difference between young and mature trees. Cuttings of white pine (*28*), for example,

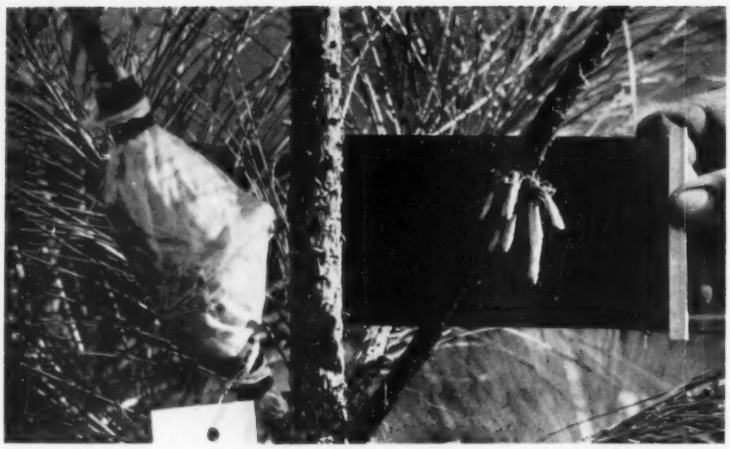

FIG. 4.—Rooots on air-layered branch of young slash pine.
*Photo from U. S. Forest Service, Southeastern Forest Experiment Station*

root easily when obtained from young trees but with great difficulty from older trees. In air-layering loblolly pine (*Pinus taeda*) ranging in age from 2 to 24 years, McAlpine (*99*) obtained excellent rooting with 2- and 3-year-old trees, at age 5 a sharp drop was noted, and at ages 17 and 24 (last two age classes used) no roots formed.

The phenomenon of physiological aging is little understood. It encompasses those changes, physiological and morphological, which occur from time of emergence of the seedling, through maturity, and finally to senility. The terms "juvenile" and "mature" are often loosely employed to express the physiological age of a part of the tree or the tree as a whole. It commonly is characterized on the basis of flowering, rootability, and simple morphological features such as leaf size and shape. Actually, the most profound changes are those within the plant tissues.

Attempts to rejuvenate tissues from older trees by grafting onto seedling stock or by rooting of cuttings have consistently failed.

Thomas and Riker (*164*) and later Patton and Riker (*124*) found no improvement in rooting of shoots taken from grafted trees made originally from scions of mature white pines. A similar response was noted by Zak (*178*) in attempts to air layer shoots on shortleaf pine (*Pinus echinata*) grafts made from trees 35 to 40 years old. Delisle (*19*) demonstrated a progressive decline in rooting accompanying aging of white pine cuttings. Rooted cuttings were planted in 1938 and grown to 4-year-old saplings. Cuttings were taken from these in 1942 and rooted. These were grown until 1946 when cuttings were removed and rooted. This was repeated in 1950 and 1954. Rootability progressively declined from the first to the last series and some saplings produced cones toward the end of the study.

Other recent work, however, has shown that it is possible to rejuvenate the mature modification of *Hedera canariensis variegata* by gibberellin treatment of rooted cuttings (*137*). It remains to be seen whether or not the rejuvenation also manifests itself in the rooting response of the treated plants. The fact that root suckers, stump sprouts, and adventitious branches root better than other parts of a mature tree (*46, 81, 143, 159*) has been considered indicative of rejuvenation by some.

Genotypic variation in rooting ability is common. Individuals within a species vary in this respect as do species within a genus. That this, at least in part, may be due to a long-lasting juvenile stage is indicated by the work of Satoo, Negisi, and Nakamura (*143*). Two clones of Cryptomeria showed a decreasing rooting ability with increasing age, while two other clones showed no significant change. Rooting of cottonwood declined after 4 years (*3*), while hemlock, in contrast, decreased only slightly by age 20 (*20*).

*Sex.*—There have been reports that male trees root sooner and better than females (*129, 156*); there can be little doubt that vegetative wood roots better than flowering cuttings (*95*).

### Anatomy of Root Formation

Two types of adventitious roots have been described: (1) morphological roots, and (2) wound roots (*95*). Their occurrence depends on the species and also varies within different parts of a tree. The primordia of morphological roots are present at the time the cuttings or air layers are prepared, while wound roots are truly adventitious and develop after the branches are placed in a favorable rooting environment. Good examples of the first type occur in the willows and some of the poplars. Bannan (*9*) traced the origin of wound roots. They originate from dormant buds (spruce and fir), near dead or injured dwarf branches (larch), and from sectors of the cambium next to fusiform initials (Canada yew, *Taxus canadensis*). In a recent and comprehensive study on the anatomy of this type of root in over 30 species of conifers, Satoo (*141*) attributed their origin to the following five tissues: (1) cambium and phloem portions of rays, (2) traces of leaf and branches, (3) meristems and traces of buds, (4) irregularly arranged parenchyma tissue, and (5) callus tissue. The roots of species difficult to root originated mostly from callus tissue.

### Environmental Factors Influencing Rooting and Their Control

*Medium.* — Although some cuttings root by being suspended in air under a continuous spray of water (*131*) it is customary to plant the cuttings in a medium; its functions are fourfold: (1) to hold the cuttings in place, (2) to retain and supply moisture, (3) to allow aera-

tion around the bases, and (4) to supply warmth to the base of the cuttings.

The factors that are of greatest importance are the ratio of air to water, and the pH of the medium (*95*). If a particular species fails to root, one of the first conditions that is usually changed is the rooting medium. This accounts for the great variety of types and combinations of media tried, such as soil, sand, water, gravel, peat, sphagnum, moss, mica, styrofoam, perlite, sawdust, and shredded bark (*14, 20, 22, 48, 49, 61, 93, 96, 104, 172*). The reports on the advantages of a particular medium are conflicting, and there is no standard type or mixture that will give best results with all species. Depending on the type of cutting, types of roots desired, and conditions under which they are propagated, there is perhaps an optimum medium for each species. However, if all other factors are favorable, most species will root in a variety of media, and often the success with a medium is not dependent upon the medium itself, but upon the watering schedule used.

Some plants, such as willows, can be rooted by placing their bases in water, but most other species need a relatively high oxygen content around the base of the cuttings for active cell division and root formation. In apple cuttings, for example, callus formation slows down when the oxygen concentration of the medium drops below 12 percent (*149*). Course, well-drained media with high water-holding capacities are, therefore, best in most cases.

*Humidity.*—Desiccation will completely inhibit root formation. Therefore, in addition to an ample amount of water supplied through the medium, a high degree of humidity must be maintained around the cuttings. This is especially important for softwood and evergreen cuttings.

Minimizing the air movement will raise the humidity around the cuttings. This can be done by placing individual bell jars over the cuttings, or by using closed propagation frames (sweatboxes) with high walls and glass tops (*94, 104*). However, when cuttings are rooted in a closed atmosphere, danger from spreading diseases may be great, and frequent sanitation is sometimes necessary (*95*). The use of some kind of humidification over the open benches eliminates this problem to some extent. Two methods are commonly used: (1) humidification alone, which involves no watering of the cuttings, and (2) misting, which maintains a continuous film of water on the cuttings (*153*).

Different types of humidfication systems are in use: Atomization through fine nozzles by centrifugal force, by air pressure, or by high water pressure. The type to be used varies with the individual and the money available. If propagation is carried out on a small scale, plastic-walled small chambers equipped with atomizers and actuated by air pressure are quite satisfactory. A fully automatic high-pressure system (*700* pounds) was installed in one of the Yale greenhouses at a cost of $3,000 to humidify 4,000 square feet of greenhouse floor space. This was the lowest priced system available and the results are very satisfactory. In addition to humidifying the air, this system cools it considerably.

The misting systems are the most recent development in vegetative propagation (*55, 59*). Their main advantage is that cuttings can be rooted in full sunlight without desiccation. Pest and disease problems have also been reported to be few under mist (*153*). Misting is especially useful with cuttings that normally root slowly.

Many types of misting nozzles are available commercially. The type and spacing to use will vary with the water pressure. The nozzles are either placed overhead and spray directly on the cuttings, or they are at the level of the cuttings and spray upwards. This latter method is the better, because it eliminates troublesome dripping.

Misting is usually necessary only during the day, and may be either constant or intermittent. Constant misting may supply too much water, which will impair aeration and lower the temperature of the medium.

Intermittent misting, commonly used for a few seconds to 1 minute out of every 5 or 10 minutes, may be controlled by solenoid valves connected to time clocks and interval timers. The mechanically controlled systems spray irrespective of the water conditions surrounding the cuttings, and the preset interval is a compromise. Other controls available have a moisture sensing device that is placed close to the foilage of the cuttings (*54*). The "electronic leaf," [9] for example, consists of a small piece of plastic with two electrical contact points. A solenoid valve is activated whenever the film of water between the two points evaporates. The amount of water applied by this system is small and is automatically adjusted to the weather.

*Temperature.*—As a general rule the air temperature surrounding the cuttings should be about 10° F. lower than that of the medium. In outside frames the air temperature can be lowered somewhat by shading the beds with lath or cheesecloth. In a greenhouse, control is rather difficult during the summer unless air conditioning is available. Carpenter and Willis (*13*) made a detailed study of a number of different cooling methods and found that the insertion of continually moist aspen excelsior pads in the south sidewall of a greenhouse and exhaust fans in the north wall lowered the temperature 17° to 21° below normal greenhouse temperatures. High-pressure humidity systems were less effective. If the greenhouse has gutters and leaders, the *inside* of the glass of the roof can be whitewashed and a flowing curtain of water can be sprayed on the roof, the water being recirculated by a simple pump. Plastic screens can be used instead of whitewashing.

*Temperature of the medium.*—Rooting is hastened by raising the temperature of the medium above that of the atmosphere surrounding the cuttings (*130*). As a general

[9] Whiteshowers, Inc., 17514 Woodward Avenue, Detroit 3, Mich.

rule of thumb, the optimum temperature of the medium is that of the mean noon air temperature during the summer growing period. Adequate bottom heat is of special importance when cuttings are propagated under intermittent water sprays or under a continuous mist, and when the cuttings are treated with auxins, because the auxins have a tendency to become inactivated at low temperatures (*79*).

In greenhouses with central heating, the exhaust flue or steam or circulating water pipes are often used to supply bottom heat to the propagation beds. The main disadvantages of these systems are the unevenness of the heat supplied and the fact that no heat is available for summer propagation. For critical experiments it is best to use electrically controlled heating cables. These lead-sheathed cables are able to maintain the desired temperature with a minimum of fluctuations, and with little danger of overheating (*130*). They are easy and efficient to operate.

*Light condition and photoperiod.* —After the cuttings are placed in the rooting medium, they need to synthesize hormones and carbohydrates. Therefore, light conditions which are optimum for photosynthesis are best, provided air temperature and transpiration do not become excessive (*25, 58, 100, 166*).

Results of the effect of photoperiodic treatments during the rooting period are often difficult to interpret. Snyder (*152*) found no effect on the rooting of *Taxus cuspidata,* but did find a considerable effect on shoot development. Plants which had been exposed to short-day conditions while in the propagation bench grew much better the following season. Nitsch (*122*), however, listed several species which rooted faster and formed more and longer roots when exposed to long-day treatment. He also showed that the treatment of the parent plant prior to the time the cuttings are taken may have a marked effect on rooting. Cuttings from a Salix plant exposed to 18-hour day rooted 100 percent; those from a plant exposed to 9 hours of light did not root at all.

### Influence of Synthetic Hormones and Other Chemicals

A voluminous literature on the use of synthetic growth regulators, vitamins, and other organic chemicals in vegetative propagation has accumulated during the past 20 years. The reader is referred to the papers of Mitchell and Rice (*115*), Thimann and Behnke-Rogers (*161*), and Mergen (*104*) for a review of the earlier literature. Information on methods of application can be found in a review by Mitchell and Rice (*115*) and in books by Audus (*7*), Avery et al. (*8*), and Leopold (*90*).

Growth regulators are usually applied by soaking the basal portion of the cuttings in an auxin solution, or by dipping the basal ends of the cuttings in a mixture of auxin and talc. Auxin solutions vary in strength from a few parts per million to as much as 400 p.p.m., and the length of treatment from a few minutes to as much as 48 hours, depending on the concentration of the solution.

Quick-dip treatments with concentrations as high as 30,000 p.p.m. have occasionally been used with good results (*37*). In large-scale operations the powder dip is preferred; with this method concentrations vary from 0.1 to as much as 2.0 percent. Optimum concentrations vary with species and with the stage of development, e.g., softwood cuttings will be damaged by the concentrations required for hardwood cuttings.

An excellent evaluation of the use of synthetic growth regulators was stated by Avery et al. (*8*): "Thus far hormones are of no advantage whatsoever in rooting cuttings of plants that are never known to root without them. Furthermore, hormones will not substitute for the usual optimum conditions of light, moisture, and temperature that must be maintained for the successful rooting of all cuttings." Possibly Mirov (*113*) was right when he stated that auxins would be beneficial if all environmental conditions were optimum. Inconsistencies in his results and in others listed below may be ascribed to insufficient environmental control. Deuber (*21*), for example, reported increased rooting of pine cuttings treated with auxin, but results were inconsistent. Many investigators (*26, 33, 34, 36, 82, 97, 98, 164*) found IBA to be stimulatory in the concentrations used. NAA and IAA also were found to stimulate rooting (*4, 18, 20, 73, 82, 90, 109, 170*).

Dorman[10] tried about 270 treatments utilizing IBA, traumatic acid, vitamins, nutrients, and fungicides in different concentrations, but was unable to evaluate the treatments conclusively because of the inconsistency of the results.

Allen and McComb (*3*) showed that cottonwood cuttings rooted more readily with treatment of 100 p.p.m., IAA or IBA; however, the cuttings which rooted in the stronger concentrations exhibited a decrease in top growth as compared to the control.

Dunn and Townsend (*34*), using the quick-dip technique, tested the response of sugar maple to IBA, NAA, naphthoxyacetic acid, p-chlorophenoxyacetic acid, and p-thiocresyl. They noted that the p-thiocresyl was inhibitory, and IBA at 0.1 percent and p-chlorophenoxyacetic acid at 0.5 percent imparted equal stimulation.

Cech (*14*) studied the effects of IAA, IBA, NAA, 2,4-D (2,4-Dichlorophenoxyacetic acid), 2,4,5-T (2,4,5-Trichlorophenoxyacetic acid), and 2,4,5-TP (2,4,5-Trichloroalphaphenoxypropionic acid) in various combinations on all ages of loblolly pine. Nonsignificant stimulation was noted for most treatments. Further experiments utilizing kinetin as the stimulatory chemical were ineffective, but some promise was found in limited experiments with several concentrations of ethylene chlorohydrin. Significant results were obtained with 1- and 5-year-old material with a treatment of 10 p.p.m. Other treat-

[10]Dorman, K. W. Unpublished data on file at the Southeastern Forest Experiment Station, Asheville, N. C.

ments with antitranspirants and vitamins were ineffective.

Contrary to the above, many investigators have reported that chemical treatments have no beneficial effect on rooting (*20, 32, 43, 69, 106, 123*).

Preliminary tests on air layers have been uniformly successful in exhibiting significant stimulation through the ages at which the rooting of cuttings is possible. Beyond this age specific variation becomes very pronounced and stimulation disappears or is nonsignificant.

Mergen (*105*) first demonstrated the significant stimulation of slash pine air layers using 0.8 percent IBA, while David (*18*) noted that 1.5 percent IAA treatment stimulated maritime pine. Johanson (*75*) found that 1.2 percent IBA was optimum for root development on slash pine air layers, while 1.6 percent IBA was inhibitory and 1.2 percent NAA was fatal. Zak (*178*) noted a significant increase in the rooting of young shortleaf pine with the application of 0.8 percent IBA.

Cech (*14*) reported that 0.8 percent IBA was most stimulatory on loblolly pine air layers from 2 to 9 years of age but that 2,4-D at 500 p.p.m. was almost as efficient. Treated 30- and 60-year-old material did not root, but an analysis of tissue proliferation indicated significantly greater physiological activity for the IBA and 2,4-D treatments. On 3-year-old grafts from 3-year-old trees, a combination of 2,4-D and 2,4-5-T most successfully stimulated root development; however, air layers made on 4-year-old grafts of one 60-year-old easily grafted clone did not root, but exhibited the greatest tissue proliferation with the IBA treatment.

Mergen and Cutting (*107*) noted that Norway spruce (*Picea abies*) and blue spruce (*P. pungens*) responded best to treatment of 0.5 percent IBA, and that higher concentrations were lethal to both species.

Inconclusive results have been reported by Hitt (*63*) with air layers of red, white, jack (*Pinus banksiana*), and Scotch pines in Wisconsin.

**Types and Preparation of Cuttings**

The two most common types of cuttings are (1) greenwood (succulent) and (2) hardwood (dormant )cuttings. A third type, the ripewood cutting, is considered by some; it is a woody cutting on which the basal end has begun to lignify (*95*). The choice and relative merits of the different types of cuttings to a large extent depend on the species and on the rooting environment which can be maintained. Differences in their responses do, of course, ultimately depend on the food and hormone balances at the time the cuttings are taken and during the rooting process.

Hardwood cuttings are apparently best for pine (*4, 14, 19, 106, 154, 162*), although Thomas and Riker (*164*) found the best response with white pine cuttings taken from July to September. Mirov (*111*) noted that pine cuttings taken in spring, i.e., softwood cuttings, were unsuccessful under California conditions and suggested that the failure was due to extremely high greenhouse temperatures.

Larsen (*83*) found a seasonal high in June and July with cuttings from Norway and Sitka spruces (*Picea sitchensis*), and similar results have been reported for white spruce (*P. glauca*) (*41*). Runquist and Stefansson (*139*) stated that moderately lignified spruce and pine cuttings root the easiest. Fillmore (*44*) had the greatest success with softwood cuttings of blue spruce.

The broadleaf species also show a distinct seasonal response. Greenwood cuttings are superior provided the proper environmental conditions can be maintained (*29, 34, 37, 82, 91*). If environmental control is poor, highly lignified hardwood cuttings may be best, at least with the easy-to-root species.

Leaf-bud and needle-fascicle cuttings are modified greenwood cuttings. The leaf-bud cuttings consist of a leaf with a stem portion and a bud attached; they are used in horticulture for special crops (*46*). Their main advantage is that a small amount of branch material yields a large number of cuttings; their disadvantage is that the bud often fails to develop in spite of good root development. The same holds for needle fascicles which have rooted successfully (*73, 163, 165, 179*).

One-year-old branch wood is usually considered the best for hardwood cuttings (*3, 4, 17, 19, 30, 34, 42, 68*). Fielding (*43*), however, found that Monterey pine (*Pinus radiata*) cuttings from 1-, 2-, 3-, and 4-year-old wood rooted equally well. Larsen (*81*) described a special technique which was very successful with aspen. Greenwood cuttings developing on detached root pieces rooted with a very high percent of success and showed excellent development.

The results of numerous tests of the type of branches to use, the length of cuttings, and the way to trim the cuttings have varied with species and from one test to another, and are not very conclusive.

Sherry (*148*) and Fielding (*43*) found that first-order branches were best. Cuttings from second-order branches were not as good, but rooted better than those from third-order branches. Allsop (*4*) found that cuttings rooted better when collected from the first laterals formed in the spring. Runquist (*139*) also had the greatest success with laterals, but Levin (*91*) showed that laterals did not root as well as terminal shoots. Shoots from the lower half of the crown are recommended for spruce (*42*). Doran (*25*) recommended that wood from fast-growing branches be used and showed that the apical half of the new growth was not as easily rooted as the basal half (*27*). Larsen (*82*) noted that the midsection of the current growth of Henry's poplar rooted more readily than either the basal or apical sections. Farrar and Grace (*42*) recommended the full length of the current growth be used in spruce.

Cuttings are usually trimmed to lengths of 4 to 8 inches before planting (*34, 36, 70, 72, 106, 150, 155*); however, optimum length ap-

parently varies with the species used. Fillmore (*44*) found that blue spruce cuttings 3 to 6 inches long rooted best, but Larsen (*83*) found 4- to 8-inch spruce cuttings reacted most favorably. Runquist and Stefansson (*139*) noted that 5- to 8-cm. (2- to 3-inch) cuttings rooted better than those from 10 to 15 cm. (5 to 7 inches) long. Allen and McComb (*3*) found 18-inch cottonwood cuttings were optimum, and Nelson and Martindale (*119*) reported that 20-inch American sycamore (*Platanus occidentalis*) cuttings were best.

The method of preparing cuttings by trimming the basal end with "snap cuts" or pruning shears just before planting is probably in most general use. Dorman[11] noted no difference in rooting ability between the right-angle cut and the slant cut; Downs (*32*) found no difference in reaction of cuttings sliced, broken, or pulled with a heel. Jacobs (*72*) also found the heel cutting no help, but Farrar and Grace (*42*) suggested that a heel might be beneficial. Warner and Went (*171*) found that shear-trimmed cuttings rooted better than knife-trimmed cuttings.

With coniferous species, removal of needle fascicles from the base of the cutting makes no difference or is harmful (*72*). Dunn and Townsend (*34*) found that sugar maple cuttings bearing fairly mature leaves rooted most successfully, and similar results have been reported for lemon cuttings (*39*).

Rooting of difficult material by grafting onto easy-to-root material has been reported with hibiscus (*45*) and citrus (*108*), but appears not to have been tried extensively with forest trees.

## Conclusion

Although much progress has been made in the vegetative propagation of forest trees, our knowledge is still insufficient to fully utilize these techniques. Grafting alone has found wide usage and is the principal method employed today. Rooting and air-layering, however, are infrequently used, and with few species. Air-layering usually gives better results than rooting but even this method is inadequate.

The mysteries of root initiation remain mostly unsolved, especially the limitation imposed by parent tree age. We are aware of the important environmental factors governing rooting but we know extremely little of the internal mechanisms controlling root formation.

Future research must, therefore, place emphasis upon studies of the physiological processes involved in graft union formation and incompatibility and in root initiation. Fundamental aspects of water relations, nutrition, and the role of hormones must be further investigated and understood, and the relationship between age and rooting must be elucidated. While empirical studies may often provide useful clues, they rarely lead to an adequate solution. Only by probing deeper into nature's secrets can we hope eventually to solve the problems of vegetative propagation.

[11] Unpublished information; see footnote 10.

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## Directory of Workers in the Economics of Forestry

The Division of Forest Economics and Policy of the Society of American Foresters is compiling a directory of people in the United States and Canada who are working currently in the general area of the economics of forestry. The utility of the directory in facilitating contacts among workers with common interests, in opening up lines of communication for workers in fringe areas, and as a fund of personal data depends in large measure upon its inclusiveness. If your present work or interest treats the economics of production, harvesting, processing, marketing or consumption of forest products and services from any viewpoint, please write to Professor A. C. Worrell, 360 Prospect Street, New Haven 11, Connecticut, for a data sheet.

# The Backcross Hybrid Jeffrey × (Jeffrey × Coulter) Pine

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THIS SPRING Region 5 (California) of the U. S. Forest Service initiated the boldest step yet taken in the application of forest genetics in California. Pollen was collected from naturally occurring hybrids of Jeffrey (*Pinus jeffreyi* Grev. & Balf.) and Coulter (*P. coulteri* D. Don) pine and backcrossed onto Jeffrey pine in the first large-scale breeding program carried out in the state by a non-research organization. The backcross seedlings are resistant to pine reproduction weevil (*Cylindrocopturus eatoni* Buch.), and will be incorporated into northern California planting projects on sites where weevil damage is anticipated.

This project has a history of cooperation between the divisions of Forest Insect Research and Forest Genetics Research of the California Forest & Range Experiment Station, Region 5 of the U. S. Forest Service, and the University of California. Its story properly begins in 1937, when a University of California botany student noticed an odd pinecone in the San Jacinto Mountains of southern California. It resembled neither the native Jeffrey nor Coulter cones, but appeared to be intermediate between the two. The tree was growing on the property of a Mrs. Braunschweiger, near Idyllwild, and was given the delightful name of "The Braunschweiger Tree". The botany group at Berkeley judged it to be a natural hybrid between Jeffrey and Coulter pine, and pollen collected in 1939 by personnel of the Institute of Forest Genetics showed about 50 percent abortion, further indicating the hybridity of the tree. This pollen was successfully used on Sierra Jeffrey pine to produce the backcross Jeffrey x (Jeffrey x Coulter), and by 1944, artificial Jeffrey x Coulter $F_1$ hybrids had been produced by the Institute of Forest Genetics at Placerville.

Meanwhile, independent events were occurring in northern California, which soon created considerable interest in these Jx(JxCl) hybrids. During the 1930's, the Forest Service had put in some large plantations of pine on the Shasta, Burney, and Big Springs brushfields. A few years after planting, the trees which had become established in these plantations began dying in great numbers. It was soon evident that the mortality was being caused by a weevil. Although native to northern California, it had gone unnoticed prior to the plantation outbreaks because in uneven-aged pine stands it kills only occasional small trees. It is most destructive on exposed sites, and can become epidemic in the favorable environment of large, even-aged plantations. The weevil attacks 2 or 3-year-old wood in seedlings and continues to be a threat until the trees reach a height of 6 feet or more.

In 1946, and for several years thereafter, forest entomologists ran weevil susceptibility and resistance tests on a number of pine species growing at the Institute of Forest Genetics. By forcing attacks of caged weevils on selected groups of trees they found that Coulter pine, sugar pine (*P. lambertiana* Dougl.), Torrey pine (*P. torreyana* Parry), the hybrid JxCl and the Jx(JxCl) backcross were the only species and hybrids of those tested which resisted attack under the cages. Consequently, in the spring of 1948, 100 Jeffrey and 100 Jx(JxCl) seedlings were planted in each of three northern California brushfields to field test the weevil resistance and general performance of the backcrosses (*4*).

In 1950, Zobel (*6*) undertook a study of the natural Jeffrey x Coulter hybrids in California. Using a hybrid index based on the morphological and anatomical characteristics of the cones, seeds and foliage, as well as biochemical properties of the oleoresins, he located and studied five areas containing such hybrids.

In 1957, Region 5 became interested in natural JxCl hybrids to be used as a pollen source for the production of Jx(JxCl) backcrosses. The author was employed

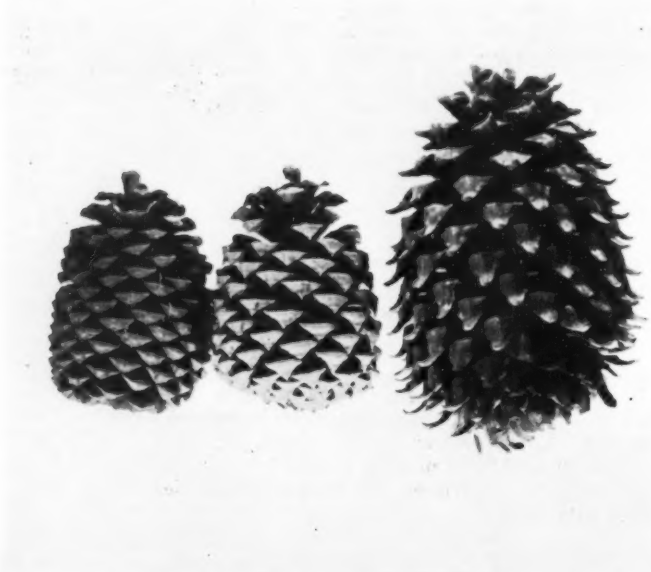

FIG. 1.—Mature cones of (left to right) Jeffrey, natural JxCl, and Coulter pine. Note particularly size of spines, the angle of the spines, and the shape of the cone scales.

to relocate Zobel's study areas and to further explore regions of Jeffrey-Coulter overlap in search of new hybrids. A modification of Zobel's hybrid index, which included only morphological characters of the cones (Fig. 1), buds and needles, was used for rapid field identification. Although not as complete as Zobel's index, it served to distinguish the intermediate hybrid types from the more extreme introgressives, which are of no value in producing Jx(JxCl) backcrosses. Since these trees were to be used as sources of hybrid pollen, qualifying criteria for their selection were (1) intermediate characters between Jeffrey and Coulter pine, and (2) anticipated pollen production by each tree in sufficient quantities to make its collection worthwhile. Twenty-three such trees were located. They are scattered in the Coast Range and mountains of southern California from about Monterey Bay to the Mexican border, and from 4000 ft. to 7000 ft. in elevation (Fig. 2).

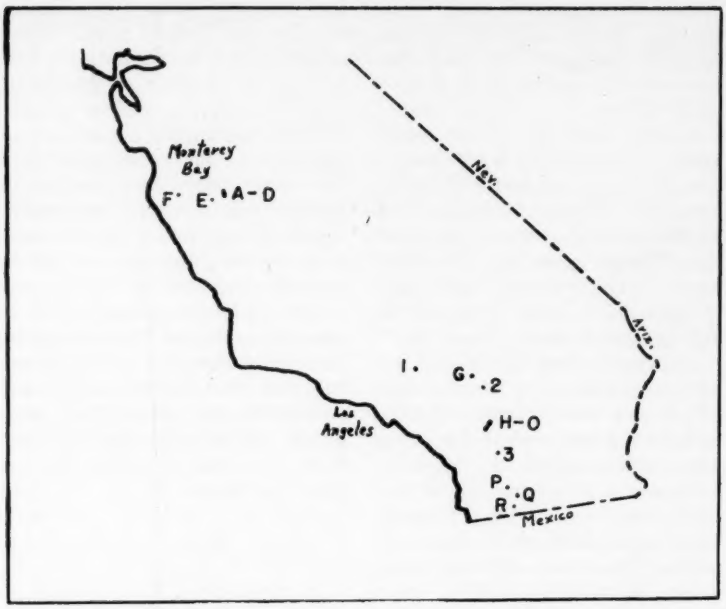


FIG. 2.—Location of natural hybrids in California. *A-D*: Ridges south and west of New Idria. *E*: Clear Creek drainage. *F*: Chew's Ridge, Santa Lucia Mountains. *G*: Lake Arrowhead, San Bernardino Mountains. *H-O*: San Jacinto Mountains, from 4000 ft. to 7000 ft. *P*: West Mesa, Cuyamaca State Park. *Q*: Laguna Mountain Area. *R*: Corte Madera Valley. Numbers 1 to 3 indicate regions of Jeffrey-Coulter overlap where no hybrids were observed. *1*: State Route 2 above Chilao Recreation Area. *2*:Converse Flat. *3*:Mt. Palomar.

Each of these intermediates used in the mass breeding program is being individually tested by controlled crosses at the Institute of Forest Genetics. Records are also being kept of the various percentages used in the breeding program, so that particular crosses may be selected for particular planting sites. This year, hybrid pollen was used in a 1000-bag program on selected 6000 ft. eastside Sierra Jeffrey pines, and in the future, Jeffrey pines selected from between 5000 ft. and 7000 ft. on the west side of the Sierra will also be used. The first seed will be ready for sowing in the spring of 1960, and it is anticipated that rapid early seedling growth will permit outplanting of 1-0 stock.

There is no doubt that the Jx(JxCl) is more weevil-resistant than either Jeffrey or ponderosa (*P. ponderosa* Dougl.) pine. Observations on the 1948 field plantings show that for every seven Jeffrey pine killed by the weevil, only one of the Jx(JxCl backcrosses was killed (*3*).

During the first ten years of testing, where Coulter pine has not been winter-killed, it has consistently and significantly outgrown both the Jx(JxCl) and Jeffrey pine. The Jx(JxCl) has maintained a somewhat intermediate growth rate, consistently and significantly[1] outgrowing the Jeffrey pine[2,3]. It is possible, however, that the early growth rate of the Coulter pine may taper off. If it does, the growth rate of the Jx(JxCl) would be expected to maintain its position between the two parent species, and would fall off accordingly.

The Coulter parent is more susceptible to cold than is Jeffrey pine. All of the Coulter pines were killed by cold in two of the three northern California plantations where weevil resistance was tested (3800 ft. & 4800 ft. elev.), while neither the Jeffrey nor Jx(JxCl) trees have been damaged. Furthermore, the early survival of Jx(JxCl) was significantly higher, even before weevil infestation, than that of the Jeffrey pine (*2*). Whether these backcrosses can survive unusually severe winters, however, will remain an open question until such winters have occurred.

Present information indicates that the wood of the Coulter pine parent is not greatly different from ponderosa and Jeffrey wood with respect to shrinkage, specific gravity and strength properties (*1*). Wood quality tests run on borings from the selected natural hybrids by the Forest Products Laboratory at Madison, Wisconsin indicated that most samples were of about average quality with respect to both Jeffrey and Coulter wood. A few samples showed unusual combinations of desirable characters.[3]

Several considerations were involved in the decision to use Jx(JxCl) backcross seedlings rather than JxCl $F_1$'s. Although $F_1$ hybrids can be obtained, frequent incompatibilities exist between individual Jeffrey and Coulter trees. The failure of these incompatible

[1]Except at a small test at 7000 ft. elevation.

[2]Hall, R. C. Unpublished data at Calif. Forestry and Range Expt. Sta., Berkeley, Calif. 1958.

[3]Callaham, R. Z. Unpublished data at Institute of Forest Genetics, Placerville, Calif. 1958.

crosses to set viable seed would lead to wasted effort in a mass breeding program. The backcross between the hybrid and Jeffrey pine, however, is almost always successful, and the weevil resistance of Coulter pine is effective in the Jx(JxCl) backcross. Furthermore, Jeffrey pine is considered to be generally a more desirable tree than Coulter pine, and the backcross Jx(JxCl) should, more nearly than the $F_1$ JxCl, resemble the Jeffrey pine in most characters.

Although young Jx(JxCl) trees have been subjected to more than 10 years of testing, relatively little is known about their behavior in more mature stages of development, or under a great variety of untested conditions. Unfortunately there is no short cut to these answers. The trees will have to be grown to maturity under a great variety of conditions. How long, then, must one wait before these trees can be employed without risk of disastrous failures?

Plans at present are to interplant one Jx(JxCl) per 3 or 4 Jeffrey or ponderosa pines. There are sound economic and biological reasons for this practice (*5*). The hybrid seedlings will cost much more to produce than Jeffrey or ponderosa seedlings. The number of high-cost seedlings necessary per acre can be sharply reduced by interplanting. If a weevil outbreak occurs, there should still be enough resistant Jx(JxCl) trees present to prevent loss of the plantation.

It seems likely that in areas where ponderosa pine attains its best growth, it will outgrow the Jx(JxCl). Similarly, Jeffrey pine may be better than the backcross on the best Jeffrey sites. Since most weevil attacks kill only a portion of the Jeffrey or ponderosa pine, the surviving Jeffrey or ponderosa trees ensure a standard of performance no worse than plantations of only these species. Wherever the Jx(JxCl) trees prove equal or superior to native pines, however, the plantation will benefit by their presence.

The choice of pollen, which is presently collected from natural intermediate hybrids of unknown pedigree, was dictated by the nonavailability of pollen from artificially produced hybrids. By using $F_1$'s of known, carefully selected parentage in the future, it should be possible to produce backcrosses of a higher quality than those being produced in the current program.

It has not yet been possible to directly cross ponderosa and Coulter pine, but Coulter's weevil resistance can be introduced into ponderosa by using the tri-species hybrid (Jeffrey x (Jeffrey x Coulter)) x ponderosa. This is a vigorous hybrid, and may prove better able to compete with ponderosa pine on good ponderosa sites. The possibilities of this hybrid, and the simpler (Jeffrey x Coulter) x ponderosa, are currently being explored at the Institute of Forest Genetics.

## Summary

The U. S. Forest Service has initiated a large-scale pine breeding program, producing Jeffrey x (Jeffrey x Coulter) backcross seedlings for use on high-weevil-risk planting sites in northearn California. In its first 10 years of field trials, this hybrid has given excellent performance. It is superior to its Jeffrey parent in resistance to reproduction weevil, initial survival, and early growth rate. The Coulter parents of the cross, however, have basic weaknesses of cold-susceptibility, possibly less-desirable form, and a possible early slowdown of growth-rate with respect to Jeffrey pine. How these backcross hybrids will behave with respect to these characters will remain in doubt until they have had time to develop more fully. Interplanting of the backcrosses with native pine will reduce the risk of using these incompletely tested trees. As it becomes possible to select all three parents involved in the Jx(JxCl) backcross, it should be possible to produce backcross progeny which are even better than those now being tested and produced.

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# The Value of Genetically Superior Seed

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THERE HAS BEEN considerable hesitancy on the part of the forest industries to collect their own seed and raise their own seedlings because of the relatively high costs as compared with those for seedlings from State nurseries. A number of southern pulp and paper companies have established seed production areas, but are disturbed by the unexpected expense of managing them and collecting the seed. Some seed has been collected, under contract, by tree surgery companies, at a price about double that for seed collected commercially from felled trees. Can these higher costs be justified?

The accompanying discussions and calculations indicate the costs are more than justified. In presenting them the authors wish to acknowledge the original thinking of F. I. Righter of the California Forest and Range Experiment Station. Righter's original calculations (unpublished), of which ours are an extension, show that hand pollination costs are economically sound for forest management conditions in California. The following calculations and examples are based on a typical pulpwood management operation for the southeastern Coastal Plain of the United States. Interested readers will find little difficulty in making similar calculations to fit the products, growth rates, and economic conditions of their respective forest regions.

## Increased Profits from Assumed Degrees of Genetic Superiority

In a typical forest management case in the South, seed costs of $3.50 to $4.00 per pound are incurred for average seed with approximately 16,000 per pound.[1] The combination of incomplete germination, endemic disease, and culling at lifting time usually results in fewer than two plantable seedlings from every three seeds sown. If 60 percent of the seeds sown produce plantable seedlings, one pound, or 16,000 seeds, will produce 9,600. Representative plantation spacings, such as 6 by 8 feet, require approximately 900 seedlings per acre. At this rate a pound of seed yielding 9,600 seedlings will provide stock for 10.67 acres.

Growth rates in southern pine plantations average one and a half cords per acre per year. Stumpage prices of $7.00 per cord are not uncommon. Thus in typical southeastern forest plantations the gross profit per acre per year approaches $10.50. Assume typical planting practices and growth rates and assume any arbitrary degree of genetic improvement, one-half of one percent, for example. A one-half percent increase in profits over $10.50 would be five and one-quarter cents per acre per year. In a 25 year rotation this would amount to $1.31. Since a pound of seed will plant 10.67 acres, the gross increase profit per pound of seed which is genetically superior by one-half of one percent would be $15.29 per pound. Discounting $15.29 by five percent annually for 25 years leaves a net value of $4.52. Thus an extra $4.52 per pound spent for seed which is genetically superior by one-half of one percent will still yield an investment profit of five percent compounded annually for 25 years. Or from another viewpoint, $0.39 extra can be spent per acre for more intensive forest management if the plants are one-half of one percent superior to wild type.

Similarly, an assumed 10 percent genetic improvement would increase the annual profits per acre by $1.05 and the gross increase in profits per acre at 25 years would be $26.30, with a gross increase in profit of $306.92 per pound of seed. Discounting this $306.92 by five percent annually for 25 years leaves $90.63 that could be spent

TABLE 1.—INCREASED 25-YEAR PROFITS FROM PULPWOOD PRODUCTION WITH VARYING DEGREES OF GENETIC IMPROVEMENT IN THE GROWING STOCK[1]

| Assumed genetic improvement[2] | Gross increased profit | | | Extra net profits | |
|---|---|---|---|---|---|
| | Per acre per year | Per acre at 25 years | Per pound of seed[3] | Per pound of seed after discounting investment cost at 5% for 25 years | Per acre after discounting 5% |
| a | 1 | 2 | 3 | 4 | 5 |
| *Percent* | | | | | |
| ½ | $0.0525 | $ 1.31 | $ 15.29 | $ 4.52 | $ 0.39 |
| 1 | 0.105 | 2.63 | 30.69 | 9.06 | 0.78 |
| 2 | 0.21 | 5.25 | 61.27 | 18.93 | 1.55 |
| 4 | 0.42 | 10.50 | 122.54 | 36.19 | 3.10 |
| 8 | 0.84 | 21.00 | 245.07 | 72.37 | 6.20 |
| 10 | 1.05 | 26.30 | 306.92 | 90.63 | 7.78 |
| 16 | 1.68 | 42.00 | 490.14 | 144.73 | 12.41 |
| 20 | 2.10 | 52.60 | 613.84 | 181.27 | 15.51 |
| 30 | 3.15 | 78.70 | 918.43 | 271.21 | 23.25 |
| 32 | 3.36 | 84.00 | 980.28 | 289.47 | 24.82 |
| 40 | 4.20 | 105.00 | 1225.35 | 361.85 | 31.07 |
| 50 | 5.25 | 131.25 | 1531.65 | 452.39 | 38.78 |

[1]Assuming pulpwood stumpage at 7.00 per cord. With pulpwood stumpage of half this amount, or $3.50, all values in the table would be halved; a 25 percent reduction in stumpage price would reduce them by one-fourth, and so on.
[2]Over an average production of 1.5 cords per acre per year from genetically unimproved stock.
[3]Assuming 1 pound of seed will plant 10.67 acres; see text.

[1]The number of seeds per pound for slash pine varies between 13,000 and 16,000. The number of seeds per pound for loblolly varies between 16,000 and 25,000. The figure 16,000 seeds per pound represents a compromise between the number per pound for slash and that for loblolly pine.

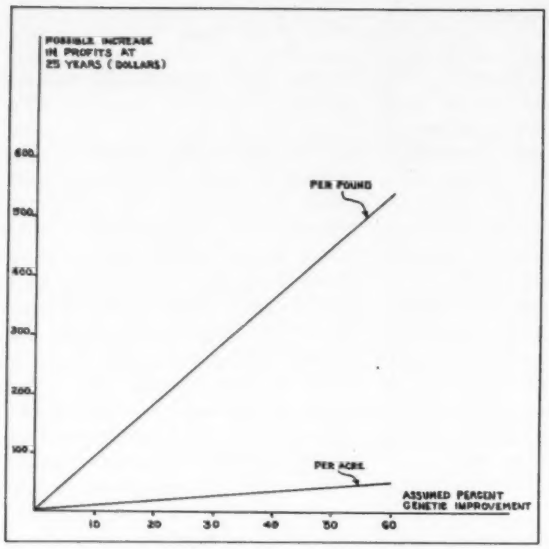


FIG. 1.—Increased profits, at 25 years, for different levels of genetic improvement, assuming a stumpage price of $7.00 per cord and an average annual growth of 1.5 cords per acre from genetically unimproved stock.

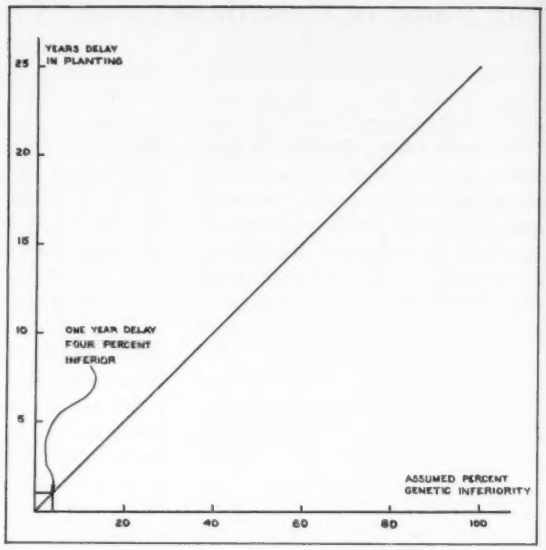


FIG. 2.—Justifiable years of delay in planting to obtain seed of average quality instead of seed of inferior strain.

per pound of seed and still obtain a five percent profit. Similar calculations show that a 30 percent improvement will result in a gross increase in profits at $78.00 per acre and that seed producing 30 percent extra profit would be worth an extra $271.21 per pound after discounting annual compound interest costs at five pervent. The general profits to be realized from varying degrees of genetic improvement are indicated in Table 1 and Figure 1.

There are no data which reveal how much genetic improvement will be obtained from such crude selection practices as are maintained in seed production areas, but when racial variation is taken into consideration it is highly conservative to assume genetic improvement of at least two percent over the use of wild type seed of unknown geographic origin and of unknown parentage. A two percent genetic improvement, by the calculations of this example, permits an expenditure of $18.93 extra per pound of seed over and above the cost of wild type seed and still allows a five percent interest profit annually. If we wish to neglect compound interest costs of five percent, the gross increase in returns from two percent superior seed is $61.27 per pound.

The matter of seed value can also be examined from the viewpoint of genetic loss. During recent years there have been local seed crop failures through most of the Southeast Coastal Plain and as a result most of the seed has been collected in central Georgia. The results of racial variation studies by Wakeley, and of preliminary studies at the University of Florida, indicate that serious losses result when seed from this central Georgia origin is used in Mississippi, Louisiana, and elsewhere (*1, 3, 4*). In Wakeley's classic loblolly pine study (*3, 4*) there were growth losses of over 60 percent resulting from the use of seed of improper geographic origin. In this instance, the tree planter in Louisiana faced with choosing between two pounds of seed, one from Georgia and one from Louisiana, could afford to spend over $600 per pound extra to obtain seed of local geographic origin rather than use the Georgia source.

If seed from the proper source is completely unobtainable it is possible to calculate the number of years that planting can economically be delayed while waiting to obtain seed of proper geographic origin.

Calculation is simplified by assuming that any wood volume, regardless of dimensions, is merchantable and that plantations will be harvested in a single cut. Once the duration of a management rotation is determined, there is fixed relationship between the decreased yield of seed of improper geographic origin and the years it pays to wait for seed of acceptable genetic quality and of proper geographic source. The relationship is independent of growth rate. However, for purposes of illustration, a 25 year rotation and 1.5 cord per acre per year growth rate are assumed in the following calculation.

A strain of seed producing yields four percent below average would produce $(1.5)\ (1 - 0.04)\ (25) = 36$ cords of wood in 25 years. The strain of average genetic quality would require $36 \div 1.5 = 24$ years to produce the same volume of wood, thus producing an equivalent amount of wood one year sooner than the improper strain. Instead of a financial loss for the year's delay in planting, there would be a saving of one year's interest on planting costs. Figure 2 and Table 2 give results of simi-

lar calculations for varying degrees of genetic inferiority. Note the fractional years of delay in Table 2. Since planting is a highly seasonal endeavor, delay for part of a year is not possible. Hence in practice the delay figures in the last column should be reduced to the next lower full year. If the assumed rotation of 25 years is doubled, then calculations show that the number of years that planting can be profitably delayed is also doubled.

TABLE 2.—JUSTIFIABLE WAITING PERIOD IN YEARS TO PLANT AVERAGE SEED IN PREFERENCE TO PLANTING INFERIOR SEED[1]

| Assumed genetic loss | Annual increment | Total increment at 25 years | Period required for average strain to duplicate inferior strain | Justifiable planting delay to obtain average seed |
|---|---|---|---|---|
| *Percent* | *Cords* | *Cords* | *Years* | *Years* |
| 4 | 1.44 | 36.0 | 24.0 | 1.0 |
| 5 | 1.42 | 35.6 | 23.8 | 1.2 |
| 10 | 1.35 | 33.8 | 22.5 | 2.5 |
| 20 | 1.20 | 30.0 | 20.0 | 5.0 |
| 30 | 1.05 | 26.2 | 17.5 | 7.5 |
| 40 | 0.80 | 20.0 | 14.7 | 10.3 |
| 50 | 0.75 | 18.75 | 12.5 | 12.5 |
| 60 | 0.60 | 15.0 | 10.0 | 15.0 |
| 70 | 0.45 | 11.3 | 7.5 | 17.5 |
| 80 | 0.30 | 7.5 | 5.0 | 20.0 |
| 90 | 0.15 | 3.8 | 2.5 | 22.5 |
| 100 | 0.00 | 0.0 | 0.0 | 25.0 |

[1]Assumed average seed strain production of 1.5 cords per acre per year or 37.5 cords at 25 years.

## Summary

The foregoing discussions indicate the value of genetically superior seed. Genetic improvements of as little as one or two percent more than justify the extra costs involved in programs of seed orchard establishment or in programs of harvesting seed from the seed production areas. Frequently, because of improper geographic origin or inferior genetic quality, the only seedlings available for planting will yield growth rates and profits four percent or more below average. The accompanying calculations show that under such circumstances profits can be increased by delaying planting for a year or more to obtain seed of acceptable genetic quality and proper geographic origin.

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## This Issue

In September 1954, the JOURNAL OF FORESTRY, in recognition of the rapidly growing interest throughout the forestry profession in forest tree improvement and genetics, published a special issue on those subjects.

This month we again present a roundup of contributions dealing with tree improvement and genetics in forestry in the belief that foresters in all fields of work wish to be kept informed of developments in the sciences and techniques involved in working for better tree crops.

We are indebted to the authors who prepared material for this issue and to the several others who offered contributions that space limitations prevented our using this month. Special thanks go to Associate Editor Philip C. Wakeley whose efforts so largely made this issue possible.

# Additional Data on Cost of Collecting Cones From a Seed Production Area

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IT HAS BEEN SUGGESTED that considerable improvement in the genetic quality of planting stock may be achieved by collecting seed from high-quality trees in natural stands (*1, 2, 3*). The method discussed by Easley (*2*) for loblolly pine requires the selection of so-called "plus" stands, a heavy roguing to remove the poorer quality trees, and, after an inteval of three or four years, the felling of the remaining trees for cone collection.

An alternate method involves the collection of cones from standing trees in a permanent seed production area. Although this has the disadvantage of requiring climbing for the cones, it eliminates the premature clearcutting of numerous superior stands and permits repeated collections from those found to be the very best.

### Present Study

To test the economic practicability of a permanent seed production area and to study means of increasing and maintaining high cone productivity, an area was established by the Texas Forest Service on the I. D. Fairchild State Forest in Cherokee County, Texas, in May 1955 (Fig. 1). The area consists of six acres of loblolly-shortleaf pine, with loblolly pine predominating. It is a mature, even-aged stand which averaged 44 years of age at time of establishment. Before thinning, the area supported a stand of over 14,000 bd. ft. (Scribner) per acre. The removal of the more crooked, large limbed, deformed or otherwise undesirable trees left 18 trees per acre with a volume of 4,090 bd. ft. The average volume per tree of those removed was 188 bd. ft. The remaining trees had an average volume of 227 bd. ft. in 1955. The trees are tall and rather clean, most of them ranging from 60 to 70 feet to the base of the well developed crowns (Fig. 2).

Beginning in the spring of 1956, fertilizer was applied to maintain major nutrients at three levels. In addition, such treatments as banding, partial girdling, and surface-root pruning have been applied to some trees. These treatments did not influence production of cones collected in 1957 because the strobili primordia were initiated in the summer of 1955 before the treatments began. However, almost all trees in the area responded well to the May 1955 release from competition by producing a bumper cone crop in 1957 (see front cover).

The first collection of cones from these trees was made in 1955 before the effects of release were felt. There was but a light cone crop and collection costs were comparatively high—$5.15 per pound of seed, exclusive of extraction, even for trees bearing 200 or more cones. Only 35 trees on the six acres had sufficient cones to warrant collection; these yielded an average of 156 cones per tree. The 1955 cone collection has been reported previously in some detail by Zobel et al. (*4*). The data obtained during the 1957 collection furnish a much sounder basis for computing collection costs. An average yield of 634 cones per tree was obtained from 75 trees. Several trees produced three bushels of cones each.

Collection techniques used in 1957 were the same as those used in 1955; i.e., trees were climbed by means of Swedish ladders and cones were pulled inward to the climber by hand or severed with a cone hook on a five-foot aluminum extension. The climbing crew varied from two to six men, on different days, but only two men were used to help the climbers and pick up cones. As a consequence, cone pick-up lagged behind work of the climbers and an extra day was needed to complete cone pick-up after climbing was finished. To avoid mixing, in cases where two or more trees were close together, cone pick-up from each individual tree was made before the next adjacent tree was climbed. Therefore only cones from well

FIG. 1.—A portion of the loblolly pine seed production area. The 18-inch width metal bands around trees prevent squirrels from climbing trees and destroying cones.

spaced and isolated trees were left for pick-up by the crew on the last day. The entire collection was completed during the first two weeks of October 1957.

Data acquired during the collection included number of cones per tree, size of cones per tree (as indicated by number of cones per bushel), and time required for collection. From an approximately 80 cone random sample from each tree, data on seed number, size and quality were obtained.

### Collection Costs

As a result of the removal of much of the pine overstory and of fertilization which is a part of the long range phase of the study, a heavy growth of grass, weeds and hardwood sprouts developed on the area. Prior to cone collection the area around the trees was mowed with a rotary brush cutter pulled behind a small tractor. This work required 10 hours for one man and equipment, at a cost of $3.00 per hour. This made the entire collection job easier, especially for cone pick-up.

Gross collection time was 205 hours for climbers and 152 hours for men picking up cones. This includes moving from tree to tree, rest time, and time spent traveling the approximately 25 miles to and from the seed production area. Actual climbing time, including putting up and taking down ladders, amounted to 155 hours and 30 minutes, or approximately 76 percent of the gross time.

Climbers were paid at the rate of $1.50 per hour and cone pick-up men at the rate of $1.00 per hour. The 75 trees climbed yielded a total of 110 bushels of cones. On the basis of rates paid, gross collection costs were $4.77 per bushel (Table 1.

Careful and thorough extraction of the seed from the 80-cone samples taken from each tree (total 14 bushels) yielded 21.1 pounds of cleaned seed or approximately 1½ pounds per bushel. Based upon this, the 110 bushels of cones yielded 167 pounds of seed, which made the gross collection cost per

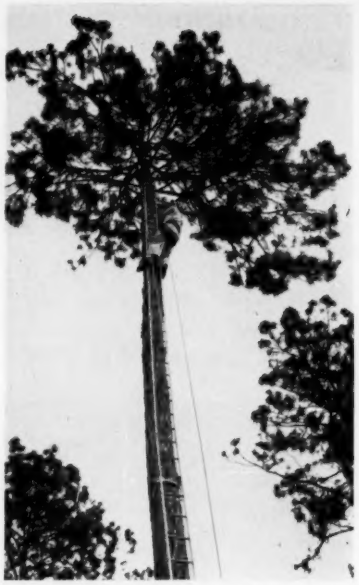

FIG. 2.—Typical crowns of the trees on the seed production area.

pound of unextracted seed $3.14 per pound. This includes only costs enumerated in Table 1, not cost of extraction, which would add an estimated 25 cents per pound. The yield of seed per cone was rather good. While one tree produced only 26 seeds per cone, the yield ranged up to 99 seeds per cone and averaged 67. Average weight per 100 seeds was 2.25 grams, equivalent to approximately 20,000 seed per pound.

The time required for cone collection per tree varied widely, depending both on number of cones and individual tree characteristics. It requires some 20 to 30 minutes to erect the Swedish ladder, climb to the top of a tall tree and return to the ground, dismantling the ladder on the way. Apart from this basic climbing time, the time required to pick cones is roughly proportional to the number of cones. Regression analysis of actual climbing time on number of cones collected indicated 9.5 minutes increase in collection time with each increase of 100 cones per tree. While variation from this regression line (Fig. 3) is due in part to different climbers, it is even more influenced by tree variation. Collection is much easier from trees with relatively small, narrow crowns than from large crowned trees with long limbs. And somewhat contrary to common opinion, the larger crowned trees in this case were not necessarily the heaviest cone producers. In fact, the two trees yielding the largest number of cones (1,800 and 1,900) were very small crowned.

### Discussion

So that cost per bushel of cones or per pound of seed may be held to a minimum in this type of collection, the yield per tree should be high. The cost could have been reduced from $4.77 to about $4.20 per bushel if trees having less than 300 cones had been bypassed. A total of only six bushels of cones was obtained from 15 such trees, and

TABLE 1.—COST OF CONE COLLECTION FROM PINE SEED PRODUCTION AREA

| Item | Total cost for collecting 110 bushels | Cost per bushel of cones | Cost per pound of seed exclusive of extraction |
|---|---|---|---|
| Climbers time on area[1] @ $1.50 per hr. | $264.00 | $2.40 | $1.58 |
| Climbers travel time[2] @ $1.50 per hr. | 43.50 | .40 | .26 |
| | 307.50 | 2.80 | 1.84 |
| Time for pick-up men on area[1] @ $1.00 per hr. | 132.00 | 1.20 | .79 |
| Travel time for pick-up men[2] @ $1.00 per hr. | 20.00 | .18 | .12 |
| | 152.00 | 1.38 | .91 |
| Transportation cost[3]—500 mi. @ $.07 | 35.00 | .32 | .21 |
| Site preparation, mowing, 10 hrs. @ $3.00 per hr. | 30.00 | .27 | .18 |
| Total | $524.50 | $4.77 | $3.14 |

[1]Time on area includes such as rest periods, moving equipment from tree to tree, as well as actual climbing and cone pick-up time.

[2]Approximately 1 hour per man per day was spent riding to and from the collection area.

[3]Pick-up truck used to transport workers.

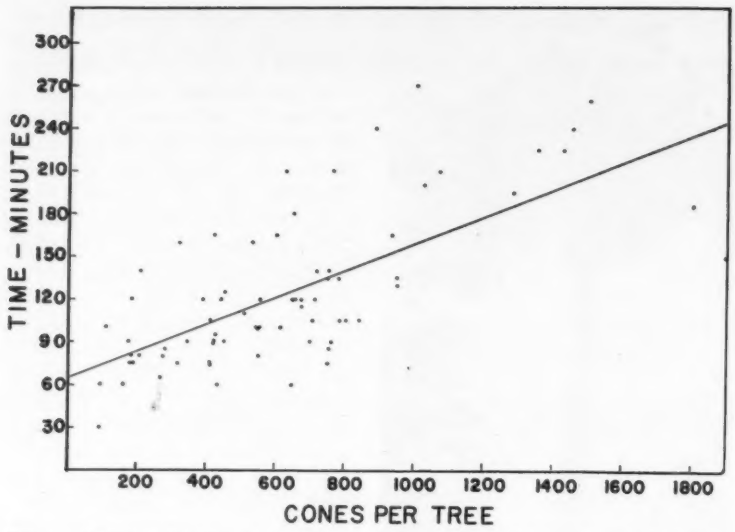


FIG. 3.—Collection time versus number of cones on individual trees. b = 9.47 minutes for 100 cones.

the total collection cost for these six bushels was over $60.00. From the standpoint of economical collection (though not necessarily from that of genetical quality of seed) a tree should have a minimum of nearly a bushel of cones[1] to justify collection.

[1]Cones averaged 432 per bushel in this collection.

The yield and cost of collection from a seed production area here discussed were such that the feasibility of obtaining loblolly pine seed in this manner is demonstrated, if the relatively small increase in cost can be justified by greater value of resulting planting stock. Until such time as progeny tests now under way reach an age at which their value can be assessed, the improvement in planting stock that can be obtained by seed production areas must remain in question. There is little doubt, however, that considerable up-grading of inherent qualities will result from more careful selection of parent trees.

## Summary

The yield and collection cost of a loblolly pine seed production area are discussed. Cones collected by climbing 75 trees the third year after release cost $4.77 per bushel for 110 bushels. The collection cost per pound of unextracted seed was $3.14. On the basis of collection time for individual trees, the study indicates that costs could be reduced by limiting collections to trees having at least 300-400 cones.

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## Correction

"A method of evaluating site quality in young red pine plantations," by M. J. Ferree, T. D. Shearer, and E. L. Stone, May 1958, page 329, Figure 2. The left-hand axis should read "Height above B.H. (Feet)." The values of the right-hand axis were misplaced upward and each should be greater by two feet.

The error originated in drafting.

# West Virginia's Unusual Pine Plantation

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Research Foresters, Northeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture

VISITORS TO THE Clover Run plantation on the Monongahela National Forest near Parsons, West Virginia, often express amazement at the vigor and growth of the eastern white pine in these plantings. Now 25 years old, with trees 65 to 70 feet tall, this white pine planting has stirred the interest and admiration of foresters and laymen alike.

Foresters familiar with both the eastern and western white pine country have remarked that this is the fastest growing stand of white pine they have ever seen. Neither blister rust or white pine weevil have marred form or impaired growth of these trees. To those concerned with planting and managing white pine, descriptive data on this plantation should be of interest and value as an example of the growth potential of the species on good sites.

[1]Stationed at the Mountain State Research Center, Elkins, W.Va.

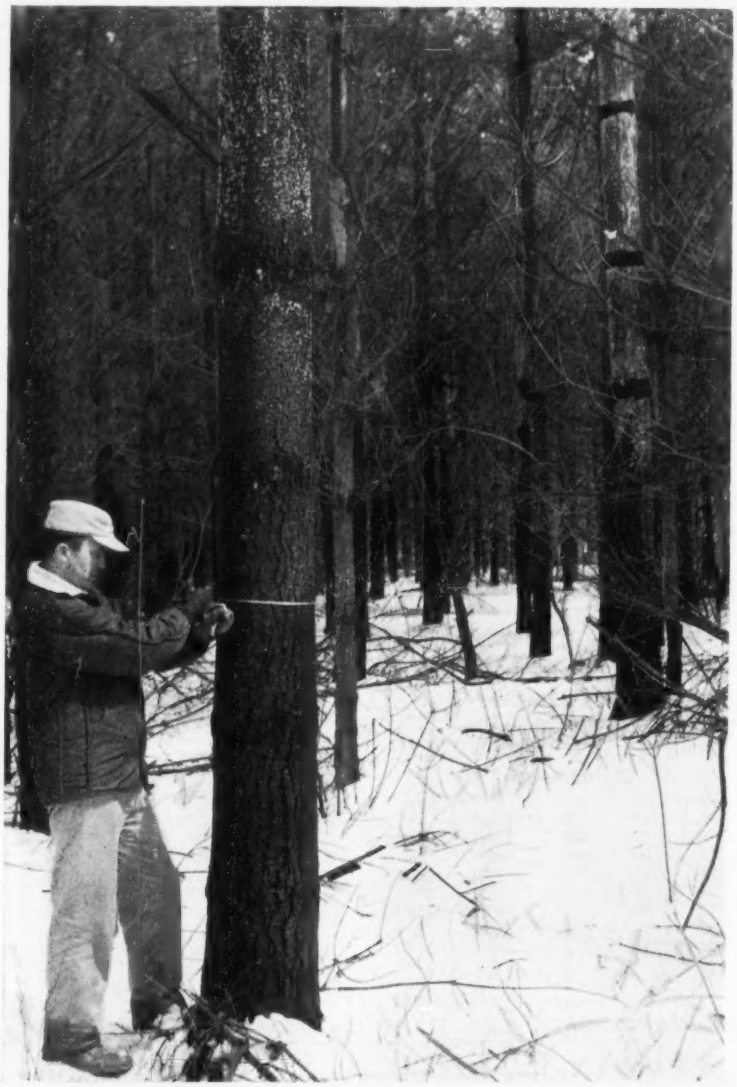

FIG. 1.—Measuring a 12-inch white pine in the Clover Run planting. This plantation, set out in the spring of 1933, has shown remarkable rates of growth. With average dominant tree heights at 67 feet, this may well be the "fastest growing stand of white pine" in the country.

## History

Before being cleared for agriculture, the site of the plantation probably supported a forest composed largely of white pine and yellow-poplar. However, it had been farmed for many years before its acquisition as part of the Monongahela National Forest.

The plantation, of about 70 acres, was set out in the spring of 1933. Approximately 10 acres were planted to pure white pine spaced 6 x 6 feet. On the remaining area, at the same spacing, white pine was interplanted with yellow-poplar, larch, white oak, black locust, hemlock, and red oak. The white pine planting stock, which consisted of 1-1 and 2-0 seedlings, was grown in a nearby U. S. Forest Service nursery from seed collected on the Pisgah National Forest in North Carolina. Except for a few yellow-poplars, the species interplanted with the white pine have all failed.

In 1953, a thinning made in part of the interplanted area removed about 6 cords per acre in intermediate and suppressed trees. Elsewhere there has been no thinning except by natural mortality.

## The Site

The plantation site, at an elevation of about 600 feet, occupies a narrow strip of flat bottomland about ¼ mile wide at the widest part. Mountains rise on either side of Clover Run above the narrow

creek valley; and part of the plantation is subject to annual flooding.

Most of the soil in the plantation is Pope gravelly silt loam or some closely associated type. Pope is a well-drained soil, with 1 to 3 feet of silt loam overlying a gravelly loamy sand deposit several feet thick above bedrock. Some of the soils associated with Pope in the plantation are not so well drained; others are more or less gravelly in the surface horizon. All are moderately acid, the pH ranging between 4.8 and 5.5. Pine appears to grow well in all these soils. A water table exists in the gravelly deposit, at least for a good part of the year, and the deeper roots of the pines probably have access to a plentiful moisture supply throughout most of every growing season.

The average annual temperature is around 50°F.; the precipitation, which is well distributed throughout the year, is about 50 inches; and the frost-free growing season is about 140 days.

### Stand and Growth Data

At 25 years of age the codominant and dominant trees in this plantation have reached an average height of 67 feet. Spot checks indicate that height growth has been generally uniform (within a range of 2 to 3 feet) throughout the whole plantation, regardless of the mixture planted. However, diameter growth of the white pine has been greater in the mixed planting due to the increase in growing space provided by failure of the other species.

In the spring of 1953, when the stand was 20 years old, d.b.h. measurements were made in portions of the pure pine plantings and also where pine had been interplanted in alternating double rows with yellow-poplar. At that time the average d.b.h. of the pure pine was 6.0 inches and that of the interplanted pine was 7.6 inches. Maximum d.b.h. was 11 inches; trees approaching this size were much more numerous in the interplanted stand. After the 1953 thinning in part of the interplanted area, the average d.b.h. of the residual pines was 8.0 inches.

In the fall of 1953, stand data were taken on two ¼-acre plots in the unthinned pure pine. Four growing seasons later, in the fall of 1957, these plots were remeasured. In addition, in 1957, four ¼-acre plots were established and measured in the interplanted area, two in the thinned and two in the unthinned section. Data from these plots are shown in Tables 1 and 2.

The unthinned pure pine plantation is now far too dense; it should have been thinned when between 15 and 20 years of age. This probably could have been done then at no cost through the sale of pulpwood from the larger trees removed. Evidence of the effect of increased density on diameter growth is shown by an analysis of average diameter growth of dominant and codominant trees. During the last 10 years, growth has been 0.22 inch a year (inside bark) while previously it had been 0.37 inch.

Since the 1953 measurement,

TABLE 1.—STAND AND VOLUME DATA (PER ACRE) OF UNTHINNED PLOTS OF PURE WHITE PINE AT CLOVER RUN PLANTATION, FALL 1953 AND 1957

| Fall 1953 | | | | | Fall 1957 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| D.b.h. | Trees | Basal area | Volume[1] | | D.b.h. | Trees | Basal area | Volume[1] | |
| *In.* | *No.* | *Sq. ft.* | *Cu. ft.* | *Bd. ft.* | *In.* | *No.* | *Sq. ft.* | *Cu. ft.* | *Bd. ft.* |
| 4 | 128 | 11.17 | ..... | ..... | 4 | 78 | 6.80 | ..... | ..... |
| 5 | 180 | 24.55 | 252.0 | ..... | 5 | 124 | 16.90 | 173.6 | ..... |
| 6 | 220 | 43.19 | 704.0 | ..... | 6 | 178 | 34.94 | 569.6 | ..... |
| 7 | 180 | 48.11 | 936.0 | ..... | 7 | 138 | 36.88 | 717.6 | ..... |
| 8 | 94 | 32.82 | 705.0 | ..... | 8 | 104 | 36.30 | 780.0 | ..... |
| 9 | 54 | 23.86 | 567.0 | 1728 | 9 | 82 | 36.23 | 861.0 | 2624 |
| 10 | 16 | 8.73 | 224.0 | 832 | 10 | 48 | 26.18 | 672.0 | 2496 |
| 11 | 2 | 1.32 | 36.0 | 148 | 11 | 24 | 15.84 | 432.0 | 1776 |
| 12 | ..... | ..... | ..... | ..... | 12 | 6 | 4.71 | 132.6 | 594 |
| Total | 874 | 193.75 | 3424.0 | 2708 | ..... | 782 | 214.78 | 4338.4 | 7490 |
| | Average d.b.h.: 6.2 inches | | | | | Average d.b.h.: 6.8 inches | | | |

[1]Volume data were computed from Site I volume tables in "Site class volume tables for merchantable timber in the Anthracite Region of Pennsylvania," by C. F. Burnham, M. J. Ferree, and F. E. Cunningham, U. S. Forest Serv. Northeast. Forest Expt. Sta. Forest Mgmt. Paper 3, 1946. Cubic-foot figures are gross volume to a 4-inch top, including bark. Board foot volumes are to a 6-inch top, based on International ¼-inch rule.

TABLE 2.—STAND AND VOLUME DATA (PER ACRE) OF THINNED AND UNTHINNED PLOTS OF INTERPLANTED PINE-YELLOW POPLAR, CLOVER RUN PLANTATION, FALL 1957

| D.b.h. | Trees | Basal area | Volume[1] | | D.b.h. | Trees | Basal area | Volume[1] | |
|---|---|---|---|---|---|---|---|---|---|
| *In.* | *No.* | *Sq. ft.* | *Cu. ft.* | *Bd. ft.* | *In.* | *No.* | *Sq. ft.* | *Cu. ft.* | *Bd. ft.* |
| *Unthinned plots* | | | | | *Thinned plots* | | | | |
| 4 | 6 | 0.52 | ..... | ..... | 4 | 8 | 0.70 | ..... | ..... |
| 5 | 52 | 7.09 | 72.8 | ..... | 5 | 18 | 2.46 | 25.2 | ..... |
| 6 | 40 | 7.85 | 128.0 | ..... | 6 | 22 | 4.32 | 70.4 | ..... |
| 7 | 50 | 13.37 | 260.0 | ..... | 7 | 28 | 7.49 | 145.6 | ..... |
| 8 | 76 | 26.53 | 570.0 | ..... | 8 | 22 | 7.68 | 165.0 | ..... |
| 9 | 70 | 30.93 | 735.0 | 2240 | 9 | 52 | 22.97 | 546.0 | 1664 |
| 10 | 60 | 32.72 | 840.0 | 3120 | 10 | 48 | 26.18 | 672.0 | 2496 |
| 11 | 42 | 27.72 | 756.0 | 3108 | 11 | 54 | 35.64 | 972.0 | 3996 |
| 12 | 20 | 15.71 | 442.0 | 1980 | 12 | 30 | 23.56 | 663.0 | 2970 |
| 13 | 8 | 7.37 | 216.0 | 1016 | 13 | 14 | 12.91 | 378.0 | 1778 |
| 14 | 4 | 4.28 | 129.2 | 648 | 14 | 2 | 2.14 | 64.6 | 324 |
| 15 | 2 | 2.45 | 76.6 | 404 | ..... | ..... | ..... | ..... | ..... |
| Total | [2]430 | 176.54 | 4225.6 | 12,516 | | [3]298 | 146.05 | 3701.8 | 13,288 |
| | Average d.b.h.: 8.4 inches | | | | | Average d.b.h.: 9.2 inches | | | |

[1]See Table 1.
[2]In addition there were 78 yellow-poplars, most of which appeared about to die, and four black cherry trees which total 13.59 square feet basal area.
[3]In addition there are 22 yellow-poplars, most of which appeared about to die, and two black cherry trees, which total 3.36 square feet basal area.

about 92 trees per acre have died.

The stand at Clover Run, even without thinning, shows a remarkable growth rate. After 21 growing seasons, the plot measurements indicate a production of 34 cords of pulpwood per acre; this increased to 43 cords during the next 4 years—a gain of 2.25 cords per acre per year for this period. At 25 years of age, average annual growth is approximately 1.7 cords. Annual board-foot increase per acre for the 4-year period is 1,195, of which about 735 feet is ingrowth, that is, trees that grew into sawtimber size (minimum of 9 inches d.b.h.) during the period. Also, at 25 years of age, the plot has a sawtimber volume of 7,490 board-feet per acre; an average annual growth over the 25 years of 300 feet.

Comparison of the 1957 data from the unthinned plots in both pure and interplanted pine suggests that the greater spacing due to suppression and death of the yellow-poplar has resulted in much greater sawtimber growth in the interplanted plots than in the pure pine. Still, as shown in the table, differences in cubic volume are insignificant.

Thinning in the interplanted area in 1953 appears to have hastened diameter growth of the residual stand. This is shown by the change in average diameter. Average d.b.h. in the unthinned section went from 7.6 to 8.4 inches, a gain of 0.8 inch; while in the thinned section, average d.b.h. increased from 8.0 inches to 9.2 inches, a gain of 1.2 inches.

This pine plantation is probably growing under near-ideal conditions. Checks have been made against recorded data from half a dozen states and Canada. These show that the height growth at the West Virginia planting overruns many others considered "good" by 30 to 75 percent.

## SCHOOL BOX SCORE
## 1958 MEMBERSHIP

| | Student Applications Received | | |
|---|---|---|---|
| | November 1958 | Total 1957 | Total 1958 |
| Alabama Polytechnic Institute | 0 | 19 | 22 |
| University of California | 0 | 30 | 56 |
| Colorado State University | 0 | 19 | 15 |
| Duke University | 0 | 13 | 3 |
| University of Florida | 0 | 6 | 22 |
| University of Georgia | 1 | 86 | 46 |
| University of Idaho | 0 | 19 | 14 |
| Iowa State College | 6 | 35 | 27 |
| Louisiana Polytechnic Institute | 0 | 18 | 5 |
| Louisiana State University | 0 | 41 | 7 |
| University of Maine | 0 | 31 | 22 |
| University of Massachusetts | 0 | 10 | 4 |
| Michigan Coll. of Mining & Tech. | 0 | 29 | 5 |
| Michigan State University | 0 | 24 | 30 |
| University of Michigan | 0 | 14 | 18 |
| University of Minnesota | 0 | 28 | 32 |
| University of Missouri | 0 | 62 | 7 |
| Montana State University | 0 | 45 | 17 |
| State University of New York | 0 | 25 | 16 |
| North Carolina State College | 0 | 36 | 1 |
| Oregon State College | 0 | 29 | 30 |
| Pennsylvania State University | 0 | 32 | 24 |
| Purdue University | 0 | 18 | 18 |
| Utah State University | 0 | 5 | 24 |
| University of Washington | 0 | 27 | 27 |
| West Virginia University | 0 | 19 | 19 |
| Yale University | 0 | 7 | 19 |
| Totals | 7 | 727 | 517 |

## SECTION BOX SCORE
## 1958 MEMBERSHIP

| | Applications Received[1] | | |
|---|---|---|---|
| | November 1958 | Total 1957 | Total 1958 |
| Alleghenv | 2 | 68 | 53 |
| Appalachian | 3 | 71 | 25 |
| Central Rocky Mountain | 0 | 24 | 15 |
| Central States | 0 | 30 | 20 |
| Columbia River | 2 | 55 | 53 |
| Gulf States | 2 | 84 | 47 |
| Inland Empire | 0 | 21 | 17 |
| Intermountain | 0 | 6 | 33 |
| Kentcky-Tennessee | 0 | 8 | 3 |
| New England | 0 | 62 | 45 |
| New York | 0 | 37 | 25 |
| Northern California | 0 | 39 | 11 |
| Northern Rocky Mountain | 0 | 49 | 25 |
| Ozark | 3 | 92 | 24 |
| Puget Sound | 0 | 61 | 48 |
| Southeastern | 1 | 132 | 105 |
| Southern California | 0 | 3 | 0 |
| Southwestern | 0 | 7 | 1 |
| Upper-Mississippi Valley | 6 | 69 | 74 |
| Washington | 0 | 10 | 1 |
| Wisconsin-Michigan | 1 | 84 | 74 |
| Totals | 20 | 1,012 | 699 |

[1]Students, Juniors, Affiliates, Associates (Initial) grade only.

# Notes

## An Idea in Truck-Mounted Ladders

FIG. 1.—Truck-mounted ladder in travelling position.

FIG. 2.—Raising the ladder.

The job of tree climbing will become increasingly important as tree-breeding programs are enlarged and as seed-production areas and orchards begin producing seed crops. In some instances, trees from selected areas have been felled to facilitate cone collection, but in seed orchards established from clonal stock of superior parentage the trees will be too valuable to cut. To gather cones from these standing trees, the collector must either climb the tree and punch the cones off while working from within the tree crown, or gather cones by some other means from a vantage point outside the crown.

As an aid to collectors, a ladder mount for a fire-fighting extension ladder has been designed. It is completely operable by one man. The mount, used on a ½-ton pick-up truck, supports a 40- to 50-foot, heavy-duty ladder made of aluminum. With this truck-mounted ladder a man may work around the outside of the crowns of trees in the 40- to 50-foot height class. Where much moving is necessary, a climber and a truck driver constitute a more efficient crew. For taller trees, this ladder may be used as a quick method of gaining access to the lower crown of the tree preparatory to climbing higher within the tree crown itself.

In traveling position (Fig. 1) the ladder rests across the top of the mount, and is strapped to the upper, forward crosspiece of the mount to prevent jostling.

When the ladder is raised, it pivots on a steel rod passed through one of the hollow ladder rungs. This stationary pivot also acts as the upper support for the ladder in the raised position. The lower portion of the ladder serves as a lever for the manual operation of raising the ladder into working position.

After raising the ladder, the base is locked into place with two steel pins, one through each ladder leg (Fig. 3). The ladder may now be extended to the desired height for climbing (Fig. 4). The extension ladder should not be raised more than one-half its length if work is to be done with the ladder tip unsupported. For higher extensions with the top of the ladder free, the ladder tip should be guyed to the front of the truck with strong rope or cable. To make a triangular brace for the ladder, two other guys, wire or rope, should be fastened

FIG. 3.—The ladder locked in the raised position.

to the top of the ladder, angled one in either direction away from the rear of the truck, and tied to fixed objects. This bracing is not necessary at extreme extensions if the tip of the ladder is placed against a solid object.

When the ladder is not in use, the entire mount can be removed from the truck body until again needed (Fig. 5).

The rectangular framework of the mount is constructed of 2x2x ¼-inch angle iron, and the projecting triangular brace holding the ladder pivot pin is made of 3x3x¼-inch angle iron. The pivot pin itself fits snugly within the ladder rung and is made of 1-inch cold-rolled steel rod.

The mount was constructed to close tolerance to eliminate any loose play at the pivot point of the ladder and at the base, where it is fastened with two pins. Figure 6 shows constructional details of the upper portion of the mount.

The ladder frame should be bolted to the walls of the pickup truck bed. Two ⅜-inch bolts through the forward uprights (by truck cab) and one through the rear upright, on each side-wall, will securely hold the frame to the truck. By using stainless steel bolts no rusting will occur, and the job of removing the frame from the truck when the need arises will be much simplified.

FIG. 4.—Ladder in the raised position with the tip unsupported.

The completed mount, without the ladder, weighs approximately 450 pounds. A 45-foot extension ladder weighs 175 pounds. The metal needed to make the rack costs about $60, and a welder with helper should be able to lay out and construct the mount in 3 days. A 40-foot, 2-section, fire-fighting extension ladder will cost about $400 plus transportation charges.[1]

The ladder can be moved in the raised position, but care must be exercised when moving the ladder in either the raised or lowered position because it protrudes well above or behind the truck. As a safety precaution, the rig should not be moved with a climber standing above the pivot rung on the ladder.

R. W. JOHANSEN
and L. ARLINE
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[1]At the Lake City Research Center two adequate ladders are in use: one war surplus ladder of unknown origin, and one 40-foot Model EL ladder made by the Aluminum Ladder Company, Worthington, Penna. Other satisfactory ladders are available, and the preceding does not constitute endorsement of this particular product by the U. S. Forest Service.

FIG. 5.—Removing ladder and mount from the truck bed.

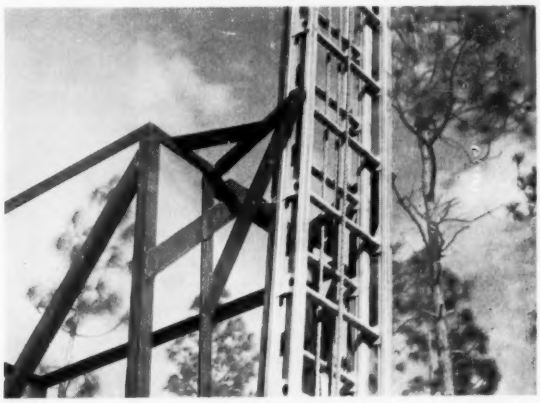

FIG. 6.—The ladder support assembly.

# The Effect of Radiation by Cobalt-60 Gamma Rays on Germination of Slash Pine Seed

Although it is well known that ionizing radiation affects growth in a number of ways, few quantitative data are available concerning its effect on germination of tree seed. Riley[1] reports that ionizing radiation may result in an increase in mutation frequency. An increase in the frequency of mutations increases genetic variability and provides more opportunity for the action of selection. Among the important problems that arise from a study using ionizing radiation are the actual effects on germination of seed. The Southern Forest Experiment Station[2] reports that the dosage of X-rays capable of killing half of stratified loblolly pine (*Pinus taeda* L.) seed was approximately 1,000 roentgens.

The present work was begun to see whether the gamma radiation from Cobalt-60 produced similar lethal effects on slash pine (*Pinus elliottii* Engelm). Another objective was to see whether ionizing radiation treatment produced any marked changes in the morphological characteristics of slash pine seedlings. Effects of ionizing radiation on seed germination are reported in this article.

Air dried, non-stratified seed of locally collected slash pine were used. This seed lot was divided into twenty one-quarter-pound samples. There were four replications for each level of irradiation and the control.

Seeds were exposed to four levels of Cobalt-60 gamma rays, at amounts of 500; 5,000; 25,000; and 100,000 roentgens. Each decaying atom of Cobalt-60 emits two gamma rays—a 1.32 mev and a 1.16 mev ray. The energy of these rays is normally given as 1.2 mev. Treatments were made by the Physical Division, Southern Research Institute, Birmingham, Alabama.

Germination tests were run for a period of 31 days on 500 seed selected at random from each replication of irradiation levels. Each germinator contained 250 seeds, i.e. two germinators were used for each replication. Germination counts were made daily. After 31 days, ungerminated seed were examined and divided into two groups, sound seed and empty seed. Germination percentages were computed on the basis of sound seed.

The remaining seed were sown in the nursery. Seedlings will be examined carefully during the growing season and then outplanted for future observation.

There seems little doubt that irradiation by Cobalt-60 gamma rays at some levels affects germination of slash pine seed. This is indicated by the total germination for 0r of 94.8 percent, 500r of 94.1 percent, 5,000r of 88.2 percent, 25,000r of 12.1 percent and 100,000r of 1.55 percent.

Irradiation at 500r did not appear to affect total germination (Table 1), but this treatment did appear to have a "stunning" effect which inhibited initial germination.

The decrease of germination by irradiation of 5,000r was highly significant.

Rates of germination appeared to be affected by 500r and 5,000r during the first 5 days only. Beginning with the 6th day and analyzing data by five-day periods, there were no real differences indicated at the 0.05 level for rates of germination between control, 500r and 5,000r. (Fig. 1).

Irradiation of 25,000r and 100,000r appear to be too high for studies involving the germination of slash pine seed. However, since frequency of mutations is correlated with the levels of radiation, dosages of 25,000r might be more effective in the long run in a tree breeding program.

Lethal dosage for fifty percent germination was found to be approximately 13,000r. This value was determined by plotting reductions in germination for different levels of treatment on logarithm paper. This dosage is considerably higher than that reported for stratified loblolly pine by the Southern Forest Experiment Station.

For all practical purposes, ionizing radiation at 100,000r is lethal to seed of slash pine. It is possible that amounts of radiation well be-

TABLE 1.—GERMINATION PERCENTAGES OF SLASH PINE SEED FOR DIFFERENT IONIZING RADIATION DOSAGES

| Days of germination | Levels of Cobalt-60 gamma radiation in roentgens | | | |
|---|---|---|---|---|
| | Control | 500r | 5,000r | 25,000r | 100,000r |
| 5 | 10.4 | 2.9 | 0.7 | .06 | 0 |
| 6 | 23.8 | 13.5 | 5.7 | .06 | 0 |
| 7 | 40.2 | 37.3 | 17.4 | .76 | 0 |
| 8 | 54.3 | 50.9 | 30.4 | 1.13 | 0 |
| 9 | 63.3 | 61.1 | 43.8 | 2.3 | 0 |
| 10 | 70.2 | 67.5 | 52.0 | 3.1 | 0 |
| 11 | 76.3 | 74.1 | 59.7 | 4.3 | 0 |
| 12 | 79.6 | 77.8 | 65.2 | 5.5 | 0 |
| 13 | 82.4 | 80.5 | 69.5 | 6.2 | 0 |
| 14 | 84.8 | 82.8 | 72.8 | 6.5 | 0 |
| 15 | 87.0 | 85.0 | 75.0 | 7.2 | 0.36 |
| 16 | 89.0 | 87.4 | 78.1 | 7.8 | 0.42 |
| 17 | 90.2 | 89.0 | 80.5 | 8.8 | 0.42 |
| 18 | 91.3 | 90.0 | 81.3 | 9.0 | 0.42 |
| 19 | 92.1 | 90.7 | 82.9 | 9.6 | 0.55 |
| 20 | 93.0 | 91.6 | 84.2 | 10.1 | 0.55 |
| 21 | 93.3 | 92.1 | 85.2 | 10.4 | 0.55 |
| 22 | 93.5 | 92.5 | 85.5 | 10.7 | 0.55 |
| 23 | 93.8 | 92.6 | 85.9 | 10.9 | 0.55 |
| 24 | 93.9 | 92.8 | 86.1 | 11.0 | 0.55 |
| 25 | 94.1 | 93.2 | 86.8 | 11.4 | 0.55 |
| 26 | 94.4 | 93.3 | 87.0 | 11.5 | 0.55 |
| 27 | 94.5 | 93.4 | 87.2 | 11.5 | 0.55 |
| 28 | 94.6 | 93.7 | 87.6 | 11.6 | 0.55 |
| 29 | 94.7 | 93.9 | 87.7 | 11.8 | 0.55 |
| 30 | 94.8 | 93.9 | 88.1 | 12.0 | 0.55 |
| 31 | 94.8 | 94.1 | 88.2 | 12.1 | 0.55 |

[1]Riley, Herbert P. Genetics and cytogenetics. John Wiley and Sons, New York. 596 pp. 1948.

[2]Southern Forest Experiment Station. Annual Report, 1957. 101 pp. 1958.

low 100,000r may be just as lethal.

To summarize: 1. Irradiation of unstratified slash pine seed with Cobalt-60 gamma rays at dosages of 25,000r and higher adversely affect the rate and degree of germination.

2. An irradiation level of 5,000r adversely affects the degree of germination of unstratified slash pine seed.

3. Irradiation dosages of 500r and 5,000r delay initial germination of unstratified slash pine seed. After germination starts, rates of germination parallel that of non-irradiated seed.

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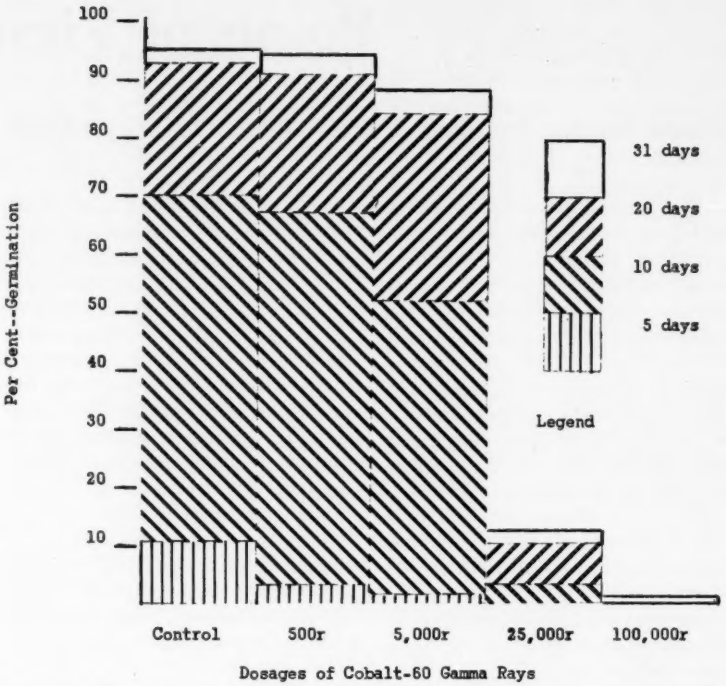


FIG. 1.—Accumulative germination of slash pine seed irradiated with Cobalt-60 gamma rays.

## Early Cone Production in Loblolly Pine[1]

Under natural conditions slash pine (*Pinus elliottii var. elliottii* Little and Dorman) and loblolly pine (*Pinus taeda* L.) trees ordinarily begin to "flower" at about 10 to 15 years. However, the production of cones with viable seed has been reported for 7-year-old slash and loblolly pine, 9-year-old shortleaf pine (*Pinus echinata* Mill.) and 15-year-old longleaf (*Pinus palustris* Mill.) (*3, 4*).

The average of the minimum ages of ovulate flower production for 55 species and varieties of pines was found to be 5.2 years. The earliest reported ages of flower production in loblolly pine were 5 years for ovulate flowers and 6 years for staminate flowers (*2*).

Stimulation of early flowering on 6-year-old slash pine trees by root-pruning, stem-injury and fertilization has been reported (*1*).

A 21-year-old loblolly pine located at the University of Georgia is bearing seed which produce seedlings that have mature cones at 4 years of age.

A total of three seedlings under this particular phenotype were observed to produce female flowers in March 1956.

Two conelets were control pollinated, but were broken off by birds. One open-pollinated conelet matured and was collected in 1957. The cone was mature in all respects and yielded 77 normal seeds.

The seeds were sown in the school nursery in March of 1958. A seedling count was made on July 14 of the same year. There were 55 healthy and normal seedlings growing from the 77 seed, a total of 72 percent.

These seedlings will be planted in appropriate designs for further observation of reproductive performance.

An opportunity for reducing age of flowering in loblolly exists in the selection of early-flowering phenotypes like the one just described. These, in turn, can be bred to other genotypes to create new early flowering and otherwise desirable varieties.

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[1]This work was done in cooperation with the Georgia Forest Research Council and the Georgia Forestry Commission. A contribution from the College Experiment Station, University of Georgia, Athens, Georgia.

# Points of View

## Forest Service Stumpage Prices—What Do They Mean?

Problems of price reporting for standing timber were reviewed in the June issue of the JOURNAL,[1] and regularly reported Forest Service data in California were found to be inadequate as the basis for a sound system of price reporting. Further consideration of the data studied discloses some of the reasons why they are unsuitable for that purpose. Such an examination also leads to the conclusion that the Forest Service's present sales policy and pricing systems are defective to a major degree.

In their study to determine the feasibility of a program for price reporting of standing timber, John Zivnuska and Ann Shideler attempted to use the quarterly summary of the U. S. Forest Service timber sales in California to develop commodity classes with average prices that could serve as a guide to price in other public timber sales. They unsuccessfully attempted to reduce the wide variation in ponderosa pine price by finding a significant relationship with independent variables contained in the reports. Independent variables tested for competitive and non-competitive sales included total volume of sale, percent of total volume in ponderosa pine and sugar pine, volume of timber per acre of sale area, log haul in truck miles, and lumber haul in truck miles.

The authors recognized that other unreported factors, such as appraised cost of road construction, might be more effective tools in reducing the variability of price reports. They also stated that factors unique to the stand, such as its structure, tree size, and quality, may be the reason for the difficulty in finding an adequate basis for commodity classification.

In addition to these factors discussed by the authors, there are others specific to Forest Service sales practices and sales procedures which affect the usefulness and validity of Forest Service sales data as guides to timber price movements by species. In its appraisals, the Forest Service generally treats each sale as a group of independent variables (species) rather than as a unit. Different indicated profit and risk margins usually are used for each species. However, the purchaser cannot decide to buy only one species. He must bid on all species and take the offering as a whole. This brings complications to any attempt to use bid data as part of a price reporting system for individual species.

For example, Douglas-fir was a part of 36 of the 65 sales studied. In one sale with a "non-competitive" price for pine the Douglas-fir was bid 45 percent above the offered rate. In three sales it was offered at the "minimum rate," a level above the appraised rate but one below which the operator cannot bid.

Incense cedar was part of 57 sales, 10 of which had this species in volumes of 500,000 feet or more. There were 19 sales listed with the cedar volume given as "nominal" or "unestimated." Ten of these 19 were included among 22 offerings of incense cedar at the 1956 "minimum rate" of $2.75. Nine of the "minimum rate" offerings were in sales with non-competitive prices for pine. Two of these had more than one-half million feet of incense cedar. In only one competitive sale with cedar offered at the "minimum rate" was there bidding above the offered rate, and in that case it zoomed to $12.99.

White fir was in all but three of the 65 sales, including 36 in which its volume was over one-half million feet. Five of these were among the 12 offerings of white fir at the "minimum rate." One minimum-rate sale included 16,800,000 feet of white fir offered at more than the Forest Service's appraisal of "fair market value." Again, in only one of the six competitive sales with white fir offered at the "minimum rate" of $2.75 was there an overbid for that species. It went for $10.75 in that instance.

In 1956 the Forest Service appraised white fir with a profit ratio of 11 percent or 12 percent in most sales. However, in offerings of white fir at the "minimum rate" the profit ratios were 1.4 percent, 3.7 percent,, 4.7 percent, 5.0 percent, 6.5 percent, etc. In at least one offering, the estimated operating cost, exclusive of stumpage and exclusive of any allowance for profit and risk, was higher than the anticipated average selling price of the lumber. In this sale the white fir was offered at about $10 per M more than the Forest Service's appraised fair market value.

Potential customers are required to submit separate bids for each of four or five species in most national forest sales in California. In 1956 there was only one commercial sale that had a single species. Another sale that year included seven species.

Bidding may be either oral auction or sealed. The successful bidder is the one who has the greatest total bid for all species, not necessarily the one who bids highest for any one species. The bidders have the opportunity to adjust selectively their total bid by the amount they raise the price of different species which have different volumes offered. A three-fold raise for one species may mean less than a 10 percent raise for the entire sale.

[1]John Zivnuska and Ann Shideler. Is Price Reporting for Standing Timber Feasible? Jour. Forestry 56:393-398. 1958.

The problem of assigning costs also affects the offered price—the level from which bidding adjustments in total price are made. If there is high development cost, most of it is now prorated to the more valuable pines by the Forest Service appraisers. In spite of this, many sales include the low-value species at "minimum rates."

The use of minimum rates brings complications. Stumpage rates were at about their highest point in California in 1956, yet 23 of the 65 sales analyzed by Zivnuska and Shideler included one or more species offered at the Forest Service's established minimum prices "below which it is believed to be wise public policy to withhold timber from sale rather than to sell for what may be expected to be temporary low values." Certainly, this introduces a factor that affects the bidding on the pine.

During a period of declining lumber market, the "minimum rate" problem is magnified. In the first quarter of this year in California 19 of 21 commercial sale offerings include one or more species at "minimum rates," and more than 40 percent of the timber volume in the entire 21 sales was offered at "minimum" levels. One offering in July included 15 million feet of white fir at $5.17 per M above the Forest Service's appraised rate.

Further complexities are brought to species prices by the use of the escalator device in government sales. Bidders know that the actual price they bid will be adjusted by the 50 percent of the change in the Western Pine Association's price index between the base period and the time the timber is cut and scaled. Some operators will bid on "minimum rate" species until the actual escalated rate reaches the "minimum rate," and then they shift to the pine. They may shift back, if different price increments are needed.

Those operators bidding on ponderosa pine late in the last quarter of 1956 had strong reasons to believe that they would actually be paying about $3 less per M than the price they were bidding. This is further complicated by the fact that four different indexes may be used in the same sale, and the changes in any two are rarely exactly the same.

The Forest Service recently improved the practice in California by regularly moving the base periods closer to the times of timber offerings. However, the effect of "base rates" in limiting downward escalation and the establishment of the new practice of double-base escalation for species appraising below "minimum rates" mean more distortion of an already confused picture of stumpage prices.

The data studied were for one specific year. When we consider the fact that changes in sales practices may take place annually and sometimes within the year, the impossibility of simple use of the reported species prices should be even more apparent.

It is evident that the prices bid for individual species are highly dependent on many factors in the individual sale offering and that such species bids cannot be taken from the sale as a whole and have meaning. The problem would be similar to trying to practice individual-species silviculture in a mixed-conifer stand while trying to grow more than one species. Intra-sale, inter-species relationships must be considered in each case.

To me, it is also evident that these conditions which make interpretation of the sales reports questionable as a price reporting system also reflect upon their usefulness as transactions evidence in the setting of profit ratios for appraisal purposes. The U. S. Forest Service should abandon the present practice of determining individual species profit ratios which are feebly based on these and other complex considerations and which often are not used. Sale offerings should be treated as a whole by Forest Service appraisers, and the appraisal should include a fair opportunity for profit on the entire offering. The Forest Service must recognize its primary obligation to encourage a maximum sustained timber harvest from the public forests.

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## Ralph K. Day (1897-1958)

Ralph K. Day, research forester at the Central States Forest Experiment Station for more than 30 years, died August 23 in Columbus, Ohio. In poor health for the past three years, Mr. Day had retired from the Forest Service Service in May of this year.

Day was born in Washington, D. C., in 1897. He received his B.S.F. degree from New York State College of Forestry in 1922; later he earned a master's degree in forestry at the Montana State University. His career with the Forest Service began in 1923. In 1927 he joined the staff of the newly established Central States Forest Experiment Station and remained there until his retirement, except for brief war-time assignments elsewhere.

# Reviews

**California Lands: Ownership, Use, and Management**

By Samuel Trask Dana and Myron Krueger. 308 pp. Illus. American Forestry Association, Washington, D. C. 1958. $4.50.

The program for American forestry developed at the Higgins Lake Conference in 1953 listed as its first recommendation concurrent national and state-by-state studies of forest land ownership patterns and problems. With a wisdom which unfortunately is not found in all national resource study proposals, the American Forestry Association has moved to advance this recommendation through a series of pilot studies which can serve to define and test the conceptions and methodology to be used in the national undertaking. This report on land in California is the result of the first such pilot study. Both the study area and the authors have been well chosen.

The lands of California vary from —282 feet to +14,495 feet in elevation, and the natural resources are as diversified and at times as spectacular as this range in elevation suggests. Since Governor Pio Pico noted in 1846 that California was "suddenly threatened by hordes of Yankee emigrants," the area has been one of chronic population explosion. With nearly 15 million highly urbanized, remarkably mobile people today, the state can look forward, not without qualms, to the period in which it will lead the nation in size of population.

Under these circumstances the intricate pattern of scattered public and private land holdings which has developed largely through a series of historical accidents is a primary factor affecting resource use and management. Professors Dana and Krueger trace the evolution of land ownership in the state, explain the present pattern of ownership, define the current problems, and demonstrate the considerations which must enter into the solution of these problems. Although such developments as urban and highway encroachment on agricultural lands are recognized, major emphasis is placed on the non-urban, uncultivated, "wildland" areas. It is stated in the preface that the study "unearthed no facts and discovered no problems with which some one was not already familiar." It might equally well be stated that no reader will fail to discover new facets to familiar problems and to gain a more complete comprehension of the institutions affecting resource management from the report.

The study is, in fact, far more than a compendium of ownership facts and problems. The presentation is given life and meaning by the distilled wisdom and sense of balance which have made the authors two of the most widely respected men in our profession. The 100 million acres of land in California are divided about equally between public and private ownership, and the abundance of problems cited for each of these major classes, to say nothing of the margin between them, is ample evidence that neither form of ownership is a panacea for resource problems. The authors suggest no alternative panaceas. Instead they provide a balanced exposition of the major factors in each situation in a spare prose which is unimpassioned yet filled with a sense of urgency.

While no solutions to problems are suggested, there is a recurring emphasis on research as the route to solutions. As the authors state, "any reader who thinks that this report recommends 'endless research' is quite right." With this emphasis, it would have been helpful if the authors had indicated something of their concept of the nature and philosophy of research. To this reviewer, some of the areas indicated for wide ranging research seem more appropriate for administrative study and decision than for formal research separated from decision-making agencies. As is appropriate, considerable stress is placed on the need for research in social values and costs, for opinion surveys, and other studies in the area of "intangibles." Here some warning is needed as to the tentative and exploratory nature of current research findings in this murky and largely undeveloped area of the social sciences. Understandably, the authors indicate no priorities among research areas, yet the reader is sure to wish that the problem analysis could have been brought to the more advanced stage of suggesting at least some broad order of priorities in the vast array of research possibilities indicated.

The report closes with a major recommendation for the establishment of a Natural Resources Council in the state to assure continuity and coordination in the consideration of wildland problems and to have neither administrative nor policy-making functions. Initially this may come as a surprise and seem to be on a different level than the preceding discussion of land ownership. Upon reflection, however, it can be seen that this proposal is the logical outgrowth of the authors' profound convictions that land ownership is simply one facet of the resource situation and that no problem in the area can be approached adequately without full recognition of the interrelationships with the complex whole.

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**Resource Training for Business, Industry, Government**

Natural Resources Study Committee. 159 pp. Illus. The Conservation Foundation, New York. 1958.

The purpose of this book is adequately stated in the introduction,

in these words: "... the necessity for conservation has been apparent in the United States for fifty years or more, and the many trained minds that have worked on its problems have come up with a great deal of theoretical knowledge and many practical techniques. The difficulty at present is not only in developing the necessary knowledge but seeing that it is put to use ... this problem is largely a matter of communication — of closing the gap between, on one hand, the universities, which train workers in the field, and, on the other, business, industry, government, and the professions, which are responsible for its application and are potential employers of the university graduates."

The book recognizes that the term "conservation" has a wide variety of definitions, dependent upon individual points of view; that various problems concerned with the best management and use of natural resources result from an inadequate understanding of broad aspects by those of specialized training or particular interest, as well as too little recognition of the importance of proper management of natural resources by the lay public. It hopes to help close the gap between knowledge of conservation techniques and the application of such knowledge by stressing the need for considering conservation in the light of entire environment rather than from the point of view of its specific parts.

To this end an invitational conference, sponsored by the Conservation Foundation in cooperation with the School of Natural Resources of the University of Michigan, was held at Ann Arbor on April 27 and 28, 1956. Twenty-nine men representing various aspects of conservation education and different interests in the use of natural resources participated in the discussions. Nine participants contributed chapters to the book. Also included are the objectives and the agenda of the conference, plus an outline of topics which were discussed, and a condensed report of the Proceedings. It concludes with committee reports and a memorandum of agreement relative to the establishment of the Natural Resources Study Committee.

Although this book does not present any startling new ideas it reflects a trend in conservation thinking—a growing awareness on the part of leaders in various aspects of the field as to the need of relating their activities to broad concepts of land management. That is the primary value of this book. The thoughts expressed reveal the wide application of varied wild land uses to the general public welfare. It should be of interest to all who consider themselves as "conservationists." It should have particular value to those in education, when evaluating training techniques and policy, and to those in business, industry, and government, when considering ways and means by which specific technical backgrounds in conservation may make practical contributions.

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**Timber and Forest Products Law**

By Harry W. Falk, Jr. 384 pp. Buckram, Howell-North Books, Berkeley, Calif. 1958. $7.50.

From long experience in legal practice in an area where logging and milling of timber has been a predominant activity, Mr. Falk is especially well qualified to write a treatise on the timber industry. In his preface the author states that he has devoted ten years of spare time to the writing of this book. Only those who have attempted to arrange in book form the vast mass of legal information regarding such an extensive industry can realize fully the task that Mr. Falk has so creditably performed.

Foresters and attorneys will find in this book a logical and illuminating discussion of the basic principles of forest and timber law and at the same time a lucid exposition of the intricacies of the law as expounded by the courts in the states of the American Union where forest and timber cases have been decided. Loggers, mill owners, and those possessed of even small areas of forest land will find a wealth of information in this volume. The lack of uniformity in legislative enactments in the 48 states and the variation in the interpretation of the law by the courts is revealed in Chapter 5.

Notwithstanding the inconsistencies and even the undeniable contradictions in certain court decisions there is a general agreement on many fundamental principles. To a large extent the lack of unanimity has arisen from the efforts of judges to avoid an interpretation of the law in particular circumstances in such manner as to deny justice to the party who seemed to be caught in a legal net when his purposes and conduct were honorable. However, these decisions become precedents and in subsequent cases in court great care may be necessary to distinguish the latter cases from the earlier one.

The discussions of the different property rights in timber and of contracts relating thereto and those regarding trespass, conversion, surveying, timber mensuration, and other forest activities will be read with keen interest and with profit by foresters. The methods of developing forest properties, forms of transportation, the obligations of buyers and sellers of timber, the measure of damages for failure in performance or for destruction of forest property are succinctly presented. There are brief discussions of both federal and state forest policies. The author exhibits a clear grasp of business principles and the seasoned judgment of an attorney who has had personal experience in the solution of the legal problems that inevitably arise in connection with the conversion of trees into useful economic products.

The book should prove especially helpful to attorneys practicing in forest regions. Not only does the author ably present the problems

of the forester and lumberman who will seek legal advice but he cites hundreds of courts decisions on typical timber cases with pertinent observations and distinguishments. A Table of Cases covers 17 pages and there is an exhaustive index—an essential feature of such a treatise.

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**Climbing Southern Pines Safely**

By E. Bayne Snyder and Harry Rossoll. Southern Forest Experiment Station, Forest Service, U. S. Department of Agriculture, Occasional Paper 159, 17 pp. Illus. 1958.

"Learn about climbing from climbers and learn to climb by climbing and climb safely by practicing safety." This sums up the thoughts behind Occasional Paper No. 159. This booklet, designed for tree breeder and cone collectors, contains tricks of the trade that would also be of value to tree surgeons, moss pickers, and linemen. The authors got to the base of the problem by surveying numerous experienced climbers in public and private organizations.

From a reading of the pamphlet, it is apparent that Tarzan of the Apes, wearing a loin cloth, swinging through the jungle on his tattered vine, a knife between his teeth, would have flunked the safety test. Following are some of the cautions and admonitions.

To climb safely, one must first have a plan, he must be properly clothed and equipped, and his actions should be steady, deliberate and he must never be caught out on a limb. Clothing must be free from encumbrances; no cuffs are wanted; skid resistant shoes (when wet or dry), and buckskin driver's gloves with inside seams are advisable.

Maintenance of assigned equipment should be the responsibility of each climber. Harness, and belt should be carefully cleaned, inspected and hung clear of sharp instruments. Wear hard hats and eye shields while on ground. Manila or manila-and-nylon ropes should be up to 150 feet and over and should be inspected daily. Keep ropes away from fire, acids, sharp tools, etc.

Small tools should have their points covered and should be shipshape. Stiff ladders, need "limbering up." Every truck should carry first-aid materials, bandages, snake-bite kit and a climbing rope.

Climb only in the daytime and never when the wind is over 25 miles per hour is the advise of the authors. Fingers get numb and branches brittle below 36°. Moisture causes feet and knots to slip. Stems under 3 to 4 inches in diameter are not generally safe.

To avoid electrocution, put a lot of distance between yourself and the tree in a thunderstorm is what the booklet says in essence.

Pass up dangerous trees containing pronounced flaws such as canker, dead limbs, decay, loose bark, broken tops, oblique branch unions.

Work in pairs, use safety belt, do not throw tools, allow no obstruction under tree.

In erecting a ladder, push only two sections at a time up from the ground. Study placement against tree carefully. Before climbing, install safety belt. Look as well as listen for "snap" of attachment. Fasten the chain of each ladder section securely as you come to it. Prune all dead branches making cuts flush so as not to snag belts or clothing. Use a hand saw. Never trust a dead limb. Do not let the safety belt dangle.

Distribute the body weight over several live limbs, step in the crotch rather than out on the limb. Use rope or belt to gain higher position. This business of "belting" and "roping" gets a little complicated but Snyder and Rossoll do a good job with a complex problem. (You can really get the low down by consulting Thompson's bulletin[1]). Even the wire hook has progressed from the days of the shepherd's crook—two kinds of wire and a colored tape finder.

Don't be reticent when up a tree and the tools begin to fall. Be prompt and loud to let the ground man know when to duck.

Just because it is easier coming down, be doubly alert. No use accelerating the process beyond practicality. Stay with the trunk rather than a loose ladder.

All climbers should have annual physical examinations. Beginners should climb only part-time and never alone. Red Cross first-aid courses should be a must. Safety meetings should be held for all climbers before climbing season.

This is a thoughtfully prepared booklet, filling a distinct need with the increasing emphasis on cone collection and tree breeding. The illustrations do much to simplify and expedite the understanding of salient points. The Southern Forest Experiment Station is to be commended for unhesitatingly departing from stereotyped publishing procedure, when to do so serves to achieve better understanding on the part of the reader.

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[1]THOMPSON, A. R. 1955. Rope knots and climbing. U.S. Dept. Int. Tree Pres. Bul. 7 (rev.), 20 pp. illus.

# Current Literature

*Compiled by* MARTHA MEELIG, *Librarian, State University College of Forestry at Syracuse University*

*Range Management Section Compiled by* DIVISION OF BIBLIOGRAPHY, *Library, U.S. Department of Agriculture*

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*The Causes of Natural Durability in Timber II. The Role of Toxic Etractives in the Resistance of Silvertop Ash . . . to Decay.* By P. Rudman and E. W. B. Da Costa. 8 pp. Australia Commonwealth Sci. & Indus. Res. Org., Melbourne. 1958. Div. of For. Prod. Technological Paper No. 1.

*Experimental Oak Wilt Control in Missouri.* By T. W. Jones and T. W. Bretz. 11 pp. Missouri Agric. Expt. Sta., Columbia. 1958. Research Bul. No. 657.

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*Oak Wilt.* By M. E. Fowler. 7 pp. Illus. U. S. Forest Serv., Washington 25. D. C. 1958. Forest Pest Leaflet No. 29. 5 cents (Govt. Print. Off.)

### Protection

*Handbook for Fire Outlooks.* U. S. National Park Serv. Div. of Ranger Activities, Washington 25, D. C. 1958.

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*Annual Legumes on Granitic Soil in the Central Sierra Foothills.* By L. R. Green and C. A. Graham. 11 pp. Illus. California Forest & Range Expt. Sta., Berkeley. 1958. Tech. Paper No. 24.

*Economics of the Utilization of Commercial Timberland on Livestock Ranches in Northwestern California.* By A. Poli and E. V. Roberts. 51 pp. Illus. California Forest & Range Expt. Sta., Berkeley. 1958. Misc. Paper No. 25.

*The Effects of Fluctuations in Weather upon the Grasslands of the Great Plains.* By R. T. Coupland. Bot. Rev. v. 24 pp. 273-318. May 1958. N. Y. Botanical Garden, New York 58, N. Y. $.75.

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*Pulping and Papermaking Experiments on Columbian Woods.* By G. H. Chidester. 16 pp. Tables. U. S. Forest Products Laboratory, Madison, Wis. 1958. Rept. No. 2118. Mimeog.

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# Society Affairs

## Officers and Council
## 1958-1959

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School of Forestry
University of California
Berkeley 4, Calif.

## Council's Column

### Foresters Need to Know More About Government

Many of us in forestry sooner or later work for government in one capacity or another. Since the day when government first assumed its natural obligations for maintaining and conserving our resources, foresters have found their services and their expertise in great demand.

Yet I venture to say that this column has rarely touched on the implications of this fact. We foresters are so immersed in our professional problems that we tend to denigrate or ignore another aspect of our activity—the political. Yet, to my mind, what some foresters are able to achieve *politically* is as important to the profession as profound research or good forest management.

I say this because expert knowledge is only half the battle for the forester who works for government. By the nature of his job, he is charged with seeing that his technical knowledge bears fruit in concrete achievement. Unless some of us are willing to risk the political fray, there can be no advance in our important forestry programs. And this means a great deal more than simply drafting a "perfect" program and then putting it into effect.

There is more frustration, more compromise, more bickering and bantering, more hot emotion, and more red tape in political life than most of us, used to the peace of our profession and possibly even university life, care to experience. It is quite possible that many foresters have been frightened away from government service for just these reasons.

Robert Moses has aptly described the talents it takes to weather such an experience.

"What is needed for such service," Moses has said, "are strong nerves, backbone, ability to argue a case by the written and spoken word, the instinct for combat, the hide of a rhinoceros, and a willingness to work like a dog for an occasional rainwashed bone. A bit of evangelism is a prerequisite too."

Moses is right. Think of some of the hurdles the professional in government service must face to get his program through.

An "ideal" proposal will scarcely ever survive. Originality is extremely difficult among the ice floes of politics. It is apt to strike hard on one of these and go to the bottom.

The public itself is the greatest hurdle Public opinion is an astounding, fascinating, and bewildering phenomenon. The slightest slip in a speech can bring an avalanche of demands and abuse down upon the head of the unwary public official. He learns to speak with a guarded tongue, always on the chance that he may find he has committed himself unwittingly to a project he can not possibly carry out.

At other times, needing public approval for a proposal heaven itself would sanction, he finds not the slightest interest among the citizenry.

We are facing this problem in Pennsylvania right now. A proposal to amend the state Constitution so that we can afford some tax relief for owners of private woodlands will be on the November ballot. We are attempting to stir up sufficient interest in the proposal so that the voters will be moved to vote on the question. Four years ago the same proposition failed simply because few citizens knew what it meant and neglected to vote on it.

Exciting the interest of our people in a proposition not directly affecting their individual pocketbooks takes a flair for the dramatic, the prodding of our publicity media, and endless re-

iteration of the issue. It is just not as simple a process as arriving at a given conclusion in the laboratory and reporting the result.

Another hurdle, of course, to the final realization of a project or policy is the political process itself. Anyone approaching a legislature for the first time for annual appropriations or for legislation close to his heart, soon finds his faith in the democratic process rudely shaken. No procedure seems at first more inefficient than that of a legislature. Haggling and compromise are the leaven in legislative output and one soon adopts the principle of "Half a loaf is better than none" in order to achieve anything at all.

Varied economic interests—those of labor, business, farmers, consumers—play an intimate part in all of this. I have just read a report that the number of registered lobbyists in Washington increased radically this year. I am sure the same is true in most state capitals. While the ordinary citizen may be apathetic toward most legislation, every lobbyist keeps a hawk's eye screwed on every bill proposed, fearful that in some subtle way, some government official—possibly a forester—might be trying to infringe upon the right of the interest he represents to earn a profit.

Political pull and patronage are the constant scourge of one who attempts to run a department which should be staffed by experts, but often includes posts designated in decades past as "political plums" rightfully belonging to some loyal party member.

The red tape one frequently encounters in government often seems the most insensible obstacle of all.

To the non-politician much of this I have described has "a slight odor." It has been an education for me to discover that the seemingly irrational in our political life sometimes has a rationale all its own.

Government and its handmaiden, politics, are dangerous and frustrating trades. But their compensations are also great. The work which government foresters perform in our park programs, in conservation, in forest management, and in research means more because it is done on a grand scale and for people, instead of profit.

I know of no way to prepare foresters entering government for the political problems they will face. But I think that they must make it a part of their education to learn the essentials of government. It is my opinion that our Schools of Forestry—and our Schools of Engineering too—would be well advised to make such a course in government a required part of the curriculum.

With a rudimentary knowledge of government and an awareness of the hazards in political life, a forester may find it easier early in his career to steer around political shoals and survive occasional buffetings. There is no feeling more satisfying than eventual triumph. The difficulties of the battle just make victory that much sweeter.

MAURICE K. GODDARD

## New York Section Studies State Forest Preserves

Fifty members of the New York Section went to the Catskill Mountains September 11 and 12 for their regular summer meeting, continuing the Section's study of the State Forest Preserves of New York.

During the two-day meeting the group toured the 580,000-acre Catskill State Park by car, on foot, and via ski-lift. The park, located only 80 miles from New York City is vital to the people of the city as a source of fresh water and recreation.

Section members observed the use of some of the 230,000 acres of State Forest Preserve lands for water production, visiting several of the largest reservoirs. At an evening meeting members saw an illustrated lecture on the longest tunnel systems in the world, supplying New York City with Catskill Mountain water.

Other subjects of the study included the use of public and private lands within the park for year-round recreational use. The members stayed both nights at the DeBruce Conservation Camp for Boys, operated by the Division of Conservation Education of the New York State Conservation Department. The tour included inspection of public campsites and the Belleayre Mountain public ski facilities. A highlight of the meeting was a demonstration of private land use for recreation at Lake Mohonk where natural beauty has been carefully conserved and developed.

## Wisconsin-Michigan Section Holds Field Meeting

In the lakes region of northern Wisconsin the summer field meeting of the Wisconsin-Michigan Section was held September 5 and 6. The newly organized Chippawa Chapter served as hosts to 126 members and guests at Boyd's Mason Lake Resort near Fifield, Wis.

A field tour was made of the Flambeau River State Forest and the Chequamegon National Forest, in which many forest recreation and forest management projects were visited. Dr. W. A. Rowlands, professor at the University of Wisconsin and coordinator for Land Use Planning and Development, State of Wisconsin, gave the banquet address, entitled "Present Day Natural Resource Area Planning Problems."

Donald Zettle, Section chairman, presided over the business meeting in which several committee reports were given and the subject of a registered foresters act for the State of Wisconsin was discussed. A Section committee is working to encourage the introduction of such an act in the state legislature.

A winter Section meeting to be held in Lansing, Mich., sometime in March 1959, with Lower Michigan as the host Chapter, was approved.

The Chippawa Chapter had as its general chairman for the summer Section meeting William R. Paddock, while Robert J. Becker served as chairman of the Arrangements Committee which included William P. Yost and Neil W. Upton.

## Coming Events

**Mississippi Forestry Association**

The twentieth anniversary meeting of the Mississippi Forestry Association will be held November 14 in the Heidelberg Hotel, Jackson, Miss.

**Western Forestry Conference**

In the Sheraton-Palace Hotel, San Francisco, Calif., the Western Forestry Conference will hold its 49th annual meeting December 10-12.

**Southeastern Section**

The Southeastern Section has scheduled its winter meeting for January 22-23, 1959 at Mongomery, Ala.

**Kentucky-Tennessee Section**

Mammoth Cave, Ky., will be the scene of the winter meeting of the Kentucky-Tennessee Section January 30-31, 1959.

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## Minnesota to Introduce Mandatory Registration Bill

A ballot regarding registration of foresters was sent to the Upper Mississippi Valley Section membership in June, culminating over five years of work by the Professional Status Committee of the Section. Of the 64 percent returning ballots, 83 percent were in favor of the principle of registration of foresters while 67 percent of the Minnesota members voted in favor of a mandatory type registration bill.

In drawing up a bill for introduction in Minnesota consideration was given to the dynamic position of forestry in that state. As a result only very general requirements are outlined in the bill.

The bill, patterned after a Minnesota law requiring registration of architects, engineers, and land surveyors, contains specific requisites which have little resemblance to those in existing laws involving registration of foresters in other states.

## Membership Applications and Advancements

Proposals for admission, advancement, and reinstatements received in the Society office during the month of September are listed below.

Action on the eligibility of those proposed for membership as listed below will be taken by the Council as of December 1958.

Communications from the voting members regarding the membership eligibility of these persons should be received in the Society office prior to that date.

### Allegheny Section

*Junior Grade*

Kiehl, C. W., forester, Pa. Dept. of Forests & Waters, Mifflinburg, Pa., Pa. State, BSF 1955.

Mattern, R. A., forester, Pa. Dept. of Forests & Waters, Port Kennedy, Pa.; Pa. State, BSF 1937.

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Fromhart, F. W.

### Appalachion Section

*Junior Grade*

Leader, M. W., forester, Koppers Co., Inc., Georgetown, S. C.; Mich. M & T, BSF 1952 (Affiliate 1954).

*Member Grade*

Bell, R. W., forester, USFS, Wytheville, Va.; Pa. State, BSF 1954 (Junior 1954).

*Affiliate Grade*

Allen, R. H., research forester, USFS, Franklin, Va.

Evans, R. W., forester, S. C. Comm. of Forestry, Pickens, S. C.

Gehrken, G. A., supv.. widlife cons., Union Bag-Camp Paper Corp., Franklin, Va.

### Central Rocky Mountain Section

*Junior Grade*

Ball, H. E., forester, USFS, Bailey, Colo. (Reinstatement).

### Columbia River Section

*Junior Grade*

Ladd, M. W., forester, Harris Pine Mills, Pendleton, Ore. (Reinstatement).

Yarosh, T., dist. asst., USFS, Prineville, Ore.; Ore. State, MF 1956.

*Affiliate Grade*

Bryant, R. S., forester, USFS, Tiller, Ore.

### Gulf States Section

*Junior Grade*

Fox, W., dist. ranger, USFS, San Augustine, Tex.; Utah State, BSF 1950 (Affiliate 1956).

Gibson, G. E., area supv., Marathon Southern Corp., Butler, Ala. (Reinstatement).

*Affiliate Grade*

Boyd, J. E., forester, International Paper Co., Gilmer, Tex.

Moreton, S. E., pres., Central Lbr. Co., Brookhaven, Miss.

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**Inland Empire Section**

*Junior Grade*

Colwell, B. E., woods mgr., Ohio Match Co., Coeur d'Alene, Idaho. (Reinstatement).

**Intermountain Section**

*Junior Grade*

Thomas, J. R., dist. forest ranger, USFS, Salt Lake City, Utah (Reinstatement).

**Kentucky-Tennessee Section**

*Member Grade*

Rock, D. A., college forester, Berea, Ky.; Yale, MF 1955 (Junior 1955).

**New England Section**

*Member Grade*

Bengtson, G. W., research forester, USFS, Lake City, Fla.; LSU, BSF 1952; Duke, MF 1955 (Junior 1952).

**Northern California Section**

*Junior Grade*

Teeguarden, D. E., asst. spec. forestry, Univ. of Calif., Berkeley, Calif. (Affiliate 1956).

**Northern Rocky Mountain Section**

*Member Grade*

Blake, C. D., forester, USFS, Missoula, Mont.; Mont. State, BSF 1953 (Junior 1953).

Kern, C. P., asst. ranger, USFS, Seeley Lake, Mont.; Mont. State, BSF 1950 (Junior 1952).

Morrison, L. W., forester, Bur. of Land Mgmt., Missoula, Mont.; Mont. State, BSF 1952; MF 1955 (Junior 1953).

**Ozark Section**

*Junior Grade*

Griswold, R. K., asst. dist. ranger, USFS, Houston, Mo. (Reinstatement).

Pierce, S. R., asst. dist. ranger, Oden Ranger Dist., Oden, Ark.; Pa. State, BSF 1954.

Woodland, R. W., asst. dist. forester, Mo. Cons. Comm., Sullivan, Mo. (Reinstatement).

*Member Grade*

Mason, D., head scaler, Dierks Paper Co., Pine Bluff, Ark.; Univ. of Mo., BSF 1955 (Junior 1955).

*Affiliate Grade*

Kennedy, J. R., forester, International Paper Co., Malvern, Ark.

Schultz, A. J., research forester, Southern Forest Expt. Sta., New Orleans, La.

**Puget Sound Section**

*Member Grade*

Crawford, R. J., cruiser, Hercules Powder Co., Spokane, Wash.; Colo. A & M, BSF 1953 (Junior 1953).

Ross, K. C., forester, Bur. of Land Mgmt., Anchorage, Alaska; Univ. of Mo., BSF 1954 (Junior 1954).

**Southeastern Section**

*Student Grade*

UNIVERSITY OF GEORGIA

Stokes, C. G.

*Junior Grade*

Baker, W. L., forester, St. Regis Paper Co., Bayard, Fla. (Reinstatement).

Bray, W. D., forester, Union Bag-Camp Paper Corp., Savannah, Ga. (Reinstatement).

Driver, C. H., dir. of forest research, International Paper Co., Bainbridge, Ga. (Reinstatement).

Dumas, K. M., consultant forester, Selma, Ala. (Reinstatement).

Rou, C. M., chief forester, A. W. Williams Inspection Co., Mobile, Ala. (Reinstatement).

*Students Eligible for Automatic Advancement*

UNIVERSITY OF FLORIDA

Haislett, B. M.

UNIVERSITY OF GEORGIA

Land, R. C. Panter, J. H.

Sims, D. H.

*Member Grade*

Newman, T. J., branch mgr., Southern Tbr. Mgmt. Service, Sheffield, Ala.; API, BSF 1951 (Junior 1952).

Patton, E. N., block forester, Allison Lbr. Co., Bellamy, Ala.; La. Tech, BSF 1951 (Junior 1951).

Thrash, F. W., field rep., Union Bag-Camp Paper Corp., Savannah, Ga. (Reinstatement).

**Upper Mississippi Valley Section**

*Student Grade*

Goins, R. A. Onken, G. A.
Hanks, L. F. Roth, P. S.
Kasile, J. D. VanZandbergen, R. L.

*Junior Grade*

*Students Eligible for Automatic Advancement*

UNIVERSITY OF MINNESOTA

Myhre, D. W.

**Wisconsin-Michigan Section**

*Junior Grade*

Bur, D. E., forester, Wis. Cons. Dept., LaCrosse, Wis.; Mich. M & T, BSF 1955.

**No Section**

*Corresponding Grade*

Atiqullah, Muhammad, deputy cons. of forests, Govt. of East Pakistan, Dacca, East Pakistan.

Bradley, E. O., British Honduras, Central America.

Lin, Yung-Huan, forester, Dept. of Agric. and Forestry, Taiwan, China.

Kwon, Nei-Tack, chief of silviculture research, Central Forest Expt. Sta., Seoul, Korea.

Taguda, E. T., Bur. of Forestry, Sto. Domingo, Ilocos Sur, Philippines.


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# Forestry News

The non-Congressional members of the Outdoor Recreation Resources Review Commission are sworn into office. Left to right: Chester Wilson, former Commissioner of Conservation for Minnesota; Bernard L. Orell, vice president, Weyerhaeuser Timber Company; Joseph Penfold, conservation director for the Izaak Walton League of America; Samuel T. Dana, dean emeritus of the School of Natural Resources, University of Michigan; Mrs. Katherine Jackson Lee, a director of American Forestry Association; M. Frederick Smith, vice president of Prudential Life Insurance Company; Laurance S. Rockefeller, chairman; President Eisenhower; and Mr. Sanderson of the White House staff who administered the oath.


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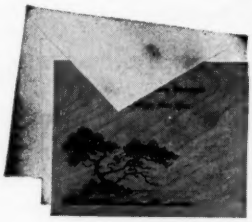

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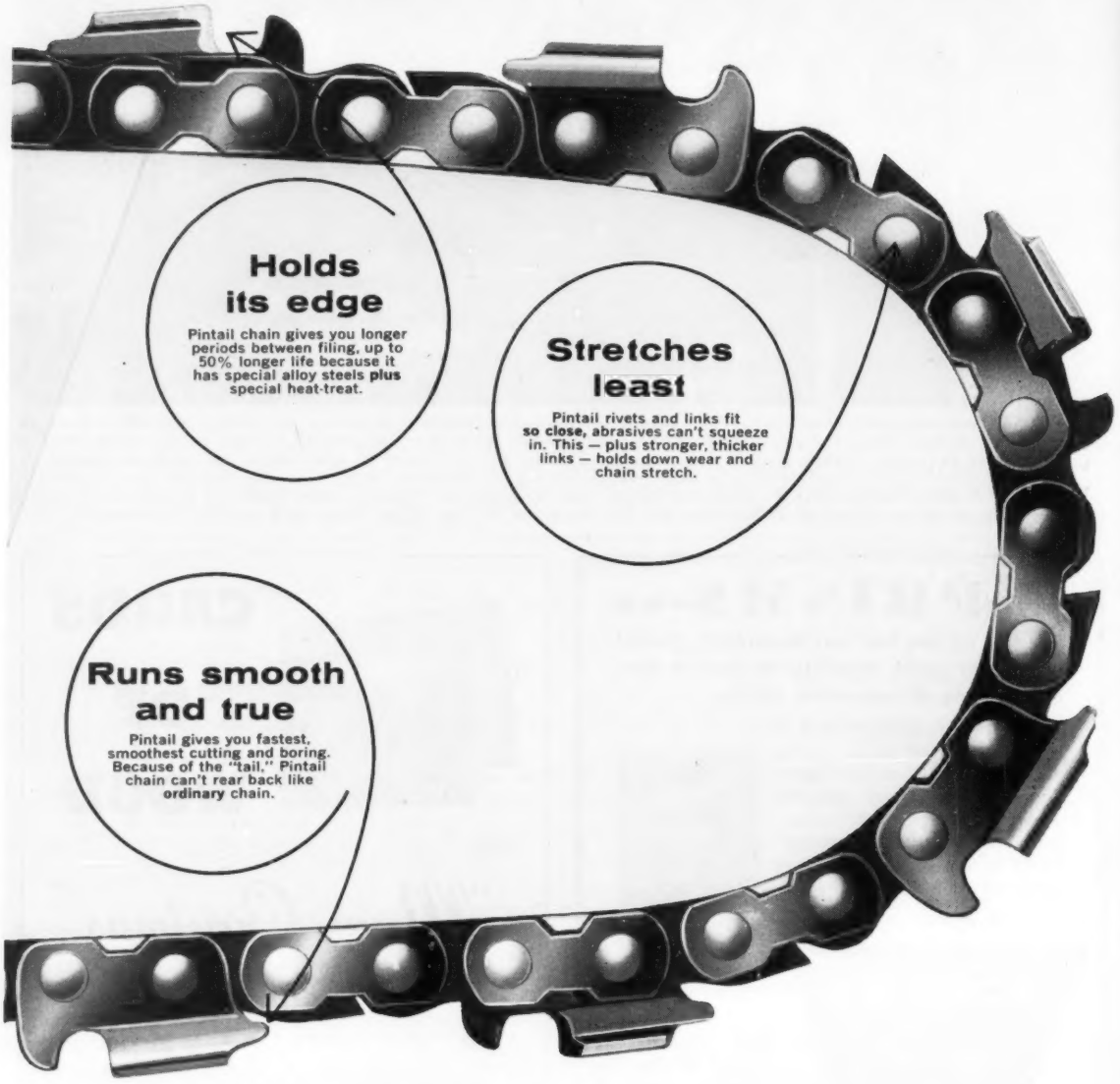

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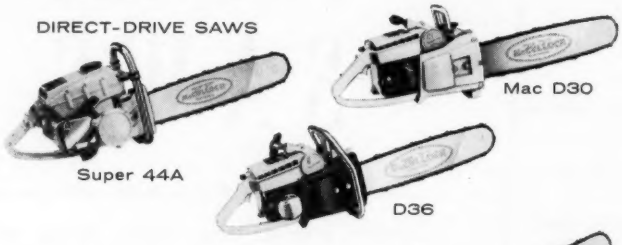
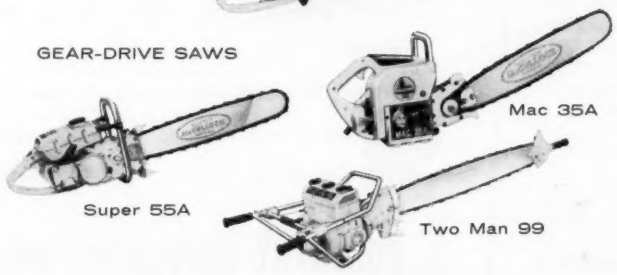



GEAR-DRIVE SAWS

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CHAIN SAWS

5-8002

## Dana and Orell Named to Outdoor Recreation Resources Review Commission

Two professional foresters have been appointed by President Eisenhower to the newly organized Outdoor Recreation Resources Review Commission. They are Samuel T. Dana of Ann Arbor, Mich. and Bernard L. Orell of Tacoma, Wash.

They are two of seven non-Congressional members of the Commission of which Laurence S. Rockefeller is chairman. The rest of the 15-member body consists of four senators and four congressmen.

The Commission will report to the President and Congress by September 1, 1961, on trends in population, leisure, transportation, and other factors connected with outdoor recreation. During the coming three years they will try to determine the amount, kind, quality, and location of outdoor recreation resources and opportunities that will be needed by the years 1976 and 2000.

The Commission will also recommend policies and programs to meet future recreation requirements at its 1961 meeting.

Dr. Dana is the former dean of the University of Michigan School of Natural Resources. He retired as dean emeritus in 1951.

Mr. Orell is vice president of Weyerhaeuser Timber Company. He was formerly state forester of Washington and was on the faculty of the University of Washington College of Forestry.

Four of the congressional members were announced in the September issue of the JOURNAL OF FORESTRY (P. 655).

## Mineral Nutrition of Forest Trees to Be Discussed

The Southeast's first conference on Mineral Nutrition of Forest Trees will be held at Duke University, Durham, N. C., December 4-5.

The purpose of the conference is to review the status of knowledge and opportunities for basic and applied research in the field of mineral nutrition of trees.

Speakers will include Harry A. Fowells, U. S. Forest Service; Robert L. Barnes, U. S. Forest Service; Norman F. Childers, Deartment of Horticulture, Rutgers University; Damon Boynton, Cornell University; John C. Cain, New York State Agricultural

Experiment Station; Paul J. Kramer, Duke University; Edward Hacskaylo, Beltsville, Md., Agricultural Research Center; F. X. Schumacher, Duke University; George Stanford, Tennessee Valley Authority; Walter E. Ballinger, North Carolina State College; E. T. York, Jr., American Potash Institute; Warren T. Doolittle, U.S. Forest Service; and Martin B. Applequist, Louisiana State University.

## Georgia Adopts Certification Standards for Forest Tree Seed

On February 8, 1958 the Georgia Crop Improvement Association accepted the *Certification Standards for Forest Tree Seed* prepared by a committee of the Georgia Chapter of the Society of American Foresters. This committee was appointed in 1956 and, under the Chairmanship of Sanford P. Darby, prepared a set of standards which received tentative acceptance in 1957.

Georgia's Standards, the first in the United States, provide for three classes of certification. Class I seed will come from progeny-tested clones in seed orchards or elite trees. (See *Forestry Terminology*, 1958 ed., for definition of terms.) Class II seed will be from seed orchards prior to completion of progeny tests or elite trees where only minimum isolation requirements are met. Class III seed will come from seed-production areas or plus trees.

Foresters are being trained as inspectors to administer and enforce the Standards. They will be directly responsible to the Crop Improvement Association, which is the legal certifying agent for Georgia. The first training session was held May 20, 1958 on property of Gair Woodlands Corporation near Swainsboro, Ga.

Foresters in Georgia look upon the Standards as a big step toward the goal of every seedling from seed of improved genetic quality. Already a number of forest-land owners have taken steps toward the production of Certified Seed.

Details of Georgia's program will be given in a later issue and copies of the Standards can be obtained from the Georgia Crop Improvement Association, Hoke Smith Annex, University of Georgia, Athens, Ga.

## Bennett Named Under-Secretary in Interior Department

Elmer F. Bennett, Solicitor of the Department of the Interior since early last year, has been given a recess appointment by President Eisenhower as Under-secretary of the Department of the Interior in charge of public land management functions.

Mr. Bennett replaces O. Hatfield Chilson who resigned as of September 30 to resume private law practice.

## Forestry Association Meets in Pennsylvania

At the annual meeting of the Pennsylvania Forestry Association, held in Bellefonte, September 12 and 13, the Leading Ridge Watershed Reserve Project was dedicated. Located in Center County, it is the first watershed research station in the Northeast.

Lloyd E. Partain, president of the Association, presided. The principal speakers were Dr. Eric Walker, president of the Pennsylvania State University; M. K. Goddard, secretary of the Department of Forests and Waters; and Ralph W. Marquis, director of the Northeastern Forest Experiment Station. These organizations jointly sponsor the project.

The Association's annual conservation award was presented as a surprise to President Partain. The speaker at the dinner was Dr. Herbert C. Storey, director of watershed management research for the U. S. Forest Service.

Among the Association's additional projects is the recently established Gifford Pinchot State Park.


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Officers elected were: president, Lloyd E. Partain; secretary, Ralph Wible; and treasurer, William H. Lynn.

Wible and Lynn are members of the Society of American Foresters.

## Private & Industrial

ARTHUR W. NELSON

### Nelson Heads New Division Created at Champion Company

Champion Paper and Fibre Company, Hamilton, Ohio, has announced the creation of a new Timber Products Division, with Arthur W. Nelson, Jr., as general manager.

At the same time, Champion announced that A. C. Shaw has been named assistant for forestry.

Nelson's woods career started with the Crossett Lumber Company, Crossett, Ark., in 1939. From 1940 to 1942 he was assistant forester and in 1942 became chief forester for the Flinkote Company, building material manufacturer, Meridian, Miss. From 1950 to 1957 he also acted as consulting forester and manager of the city of Meridian's municipal watershed. He joined Champion in 1957 as special resources consultant at the company's Texas Division, Pasadena, Tex.

A native of Chicago, Ill., Nelson was graduated from the University of Idaho with a bachelor of science degree in forestry and obtained his master's degree from the Yale University School of Forestry.


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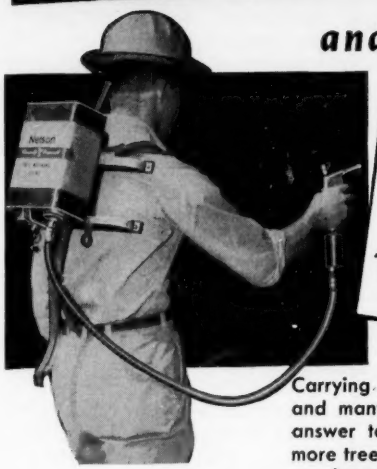

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## Young W. Rainer Named to AFPI Post

Young W. Rainer, formerly of Greensboro, N. C., has been appointed forester for American Forest Products Industries, Inc.

The appointment was announced by C. A. Gillett, AFPI managing director.

Rainer, for the past three and a half years area forester for Southern Pulpwood Conservation Association, succeeds John C. Witherspoon, who resigned to become assistant forester-manager of SPCA, Atlanta, Ga.

A graduate of Alabama Polytechnic Institute, Auburn, Rainer is a veteran of World War II and before joining SPCA was with the Alabama Division of Forestry.

As AFPI forester, he will assist Chief Forester James C. McClellan in administering the Tree Farm program and in developing the new Busy Acres program, recently announced by AFPI.

## Forestry Suppliers, Inc. Opens West Coast Office

Forestry Suppliers, Inc., of Jackson, Miss., has announced the opening of a West Coast office with Eugene D. Marshall, forest products consultant, as its West Coast representative. Mr. Marshall will maintain offices at 403 Court Avenue, Ventura, Calif.

Mr. Marshall, who for a decade headed the Forest Products Department of Texas A & M College, received his B.S. in forestry from Purdue University in 1934, and his M.S. from the University of California in 1938. His experience includes service with the U. S. Forest Service. He has been a forest products consultant since 1953

## Forest Genetics Institute to Expand Facilities

Facilities for the Northern Institute of Forest Genetics at Rhinelander, Wis., are being expanded. A new laboratory building will be constructed and greenhouse space will be increased.

The new building will have laboratories, a library-conference room, and the usual offices for technical men and their assistants. The laboratories will be equipped for studies in genetics and in physiology, anatomy-histology, and biology as they relate to tree breeding.

There will also be a cold storage room and four growth rooms where light, temperature, and humidity can be regulated. Two rooms will have fa-

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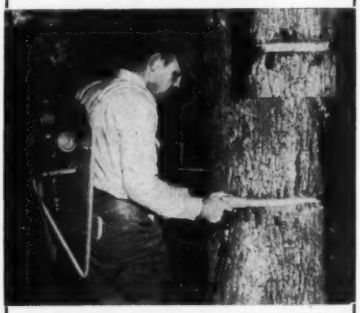

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cilities for pollen extraction and storage.

The Hugo Sauer Nursery, which is adjacent to the Genetics Institute and operated by the Wisconsin Conservation Department in cooperation with the U. S. Forest Service, will provide space for field testing early survival and growth of the experimental plants.

Dr. Hans Nienstaedt is the research forester in charge of the Institute at Rhinelander.

### Witherspoon Joins SPCA Staff

John C. Witherspoon, forester, American Forest Products Industries, Inc., has been appointed assistant to H. J. Malsberger, general manager of the Southern Pulpwood Conservation Association, Atlanta, Ga. Mr. Witherspoon began his duties September 1.

After receiving his B.S. degree in forestry from Iowa State College in 1940 Mr. Witherspoon worked throughout the South in various forestry occupations. He was formerly assistant state forester in South Carolina. In that position he was in charge of public relations for the Division of Forestry and the Division of State Parks. He joined the AFPI staff in 1955.

### Hoskins Honored for Role in Vocational Forestry Education

Robert N. Hoskins, general forestry agent for the Seaboard Air Line Railroad, of Norfolk, Va., was honored at the recent convention of the American Vocational Association in Buffalo, N. Y. for his interest and support of vocational education in forestry.

Mr. Hoskins, in his capacity as general forestry agent for the Seaboard Air Line, was instrumental in establishing the first regional farm youth forestry program with all-day students enrolled in vocational agriculture some 14 years ago.

Seaboard has moved its general offices, including the Forestry Division, from Norfolk to Richmond, Va.

### Scott Paper to Establish Tree Nursery Near Mobile

Scott Paper Company is planning to establish a forest tree nursery near Mobile, Ala.

The nursery, estimated to cost in excess of $100,000, will be able to produce 12,000,000 seedlings each year.

Most of the seedlings to be grown in the nursery will be planted on lands owned and operated by Scott Paper Company in Alabama and Mississippi. The remaining portion of the nursery's tree seedling output will be made available to owners of small woodland tracts. It is hoped that the first seedlings will be ready for planting by the winter of 1959.

### Forestry Students Receive Financial Aid

A number of companies and private organizations have given scholarships to forestry students recently.

St. Regis Paper Company has awarded its five $1,600 undergraduate scholarships to: Allan F. Gordon, Sr., University of Maine, Orono; Bivin C. Broughton, Alabama Polytechnic Institute, Auburn; Duncan A. Roush, University of Georgia, Athens; Paul D. Wilder, University of Florida, Gainesville; and George H. Quinn, Jr., Montana State University, Missoula.

A new $600 fellowship, established at the North Carolina State College, Raleigh, by the Rayonier Foundation of New York City, was awarded to Thomas H. Eek, a junior in the pulp and paper curriculum.

Three pulp and paper technology students have received $500 scholarships provided by the A. E. Staley Manufacturing Company. They are: Edgar E. Moore, Western Michigan College, Kalamazoo; James H. Allen, State University College of Forestry at Syracuse University, Syracuse, N. Y.; and Jacob Thigpen, Jr., North Carolina State College, Raleigh.

John M. Goldman has received a $250 scholarship from the Texas Forestry Association to complete forestry studies at Louisiana State University, Baton Rouge. He has completed two years at A & M College of Texas, College Station.


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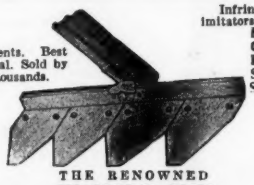
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## Public

### Endersbee Given Interior Department's Service Award

William J. Endersbee of Washington, D. C. was one of 33 employees of the Department of the Interior who received Distinguished Service awards in a September awards ceremony.

Mr. Endersbee is a member of the Technical Review Staff. He has had 37 years of service with the Department of the Interior.

The Distinguished Service Award, the highest honor conferred upon employees by the Department, is given for outstanding scientific contribution, outstanding ability in the performance of duty, or other exceptional service to the public.

### Sartz Heads New Watershed Research Unit

Richard S. Sartz, a specialist in forest and watershed research, has been appointed research center leader at the new La Cross (Wis.) field unit of the Lake States Forest Experiment Station.

The La Crosse field unit was established this year as a center for research in watershed problems related to forest conditions and use.

Mr. Sartz graduated from the forestry school at Pennsylvania State University. As an employee of the Forest Service, he has conducted watershed research in Pennsylvania, on the Columbia River Basin in Oregon, and watersheds in the New England States. His most recent assignment was at the Laconia, N. H., field unit of the Northeastern Forest Experiment Station.

### McKee New Deputy Minister of Forests in British Columbia

On September 1, Robert Gerald McKee assumed the duties of Deputy minister of Forests for British Columbia.

Mr. McKee received the appointment after 37 years' affiliation with the British Columbia Forest Service.

He graduated from the University of British Columbia with a bachelor of science (forest engineering) degree in 1924.

### Kennedy Assigned to Rural Development Program

Regional Forester A. W. Greeley of Milwaukee has announced that Glen E. Kennedy of his staff was reassigned to head Forest Service participation in rural development programs in the North Central Region. In the Region there are 17 counties in seven states designated as pilot areas where intensive study and improvement is under way.

Mr. Kennedy's 24 years of experience with the Forest Service includes work in North Carolina, Missouri, Minnesota, Indiana, and Ohio. His most recent position has been in the regional office, Division of State and Private Forestry on watershed management activities.

### Richard Marston Transfers to Central States Station

Richard B. Marston has transferred from the Intermountain Forest and Range Experiment Station to the Central States Forest Experiment Station at Columbus, Ohio, as project leader in watershed management research in Ohio, W. G. McGinnies, director of the Central States Station announced recently.

Mr. Marston is a veteran of 19 years with the Forest Service, all of which have been spent at the Intermountain Station. He moved to Columbus from


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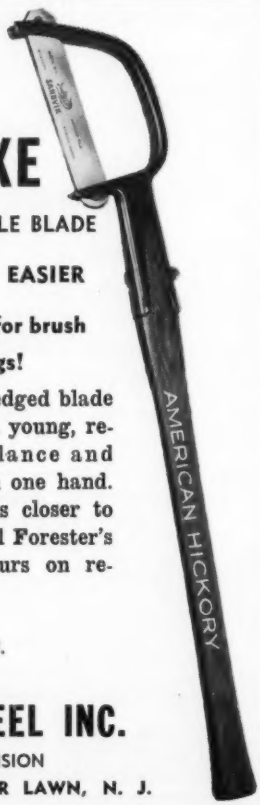


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the position of acting leader of the Wasatch Research Center at Ogden, Utah.

A native of Utah, Marston graduated in forestry from Utah State Agricultural College in 1940. He received a master of science degree from the University of California in 1948.

### Herrick Chosen for Washington Staff

David E. Herrick, forest technologist in the Carbondale Forest Research Center and recently appointed to part-time teaching in the Southern Illinois University department of forestry, transferred to Washington, D. C., October 1 as a staff specialist in the U. S. Forest Service's Division of Forest Economics Research.

Herrick has been with the U. S. Forest Service since 1951 and has been at the Carbondale Center for five and one-half years. He formerly was a forestry instructor at Iowa State College for three years and received his master's degree in forest products utilization there.

### David W. Myhre Named Photogrammetrist

David W. Myhre has been appointed photogrammetrist on the New Orleans staff of the Southern Forest Experiment Station. He replaces Thomas E. Avery, who recently transferred to the Washington, D. C., office of the Forest Service.

Myhre, a native of Battle Lake, Minn., was graduated from the forestry school of the University of Minnesota in 1956, and obtained his Master's degree there in 1958. He has worked with the Forest Service in Colorado and Montana, and conducted research in photogrammetry during his graduate studies.

### C. R. Lockard Head of National Log Grading Project

Charles R. Lockard has been appointed to a newly created post in the Washington Office of the U. S. Forest Service. He will take charge of the project of national log grading.

Until his transfer in mid-August, Lockard was chief of the Division of Forest Utilization Research at the Northeastern Forest Experiment Station.

Mr. Lockard received his forestry training at the New York State College of Forestry, Syracuse University, and at Harvard University. For the past 34 years he has worked in private industry, state forestry, the U. S. Agricultural Extension Service, national forest administration, and Forest Service research.

### Wolfe, Bowerman Move to Region 6 Headquarters

According to an announcement by Regional Forester J. Herbert Stone, Harry M. Wolfe is being added to the Pacific Northwest Region's staff, Portland, Ore., in the Division of Engineering. He will have responsibilities in planning an adequate forest trails system in the national forests of Washington and Oregon.

Transfer of Harold R. Bowerman to the section of land classification of the Portland office has also been announced by Mr. Stone.

Wolfe has been on the Wallowa-Whitman national forests staff and has lived in Baker, Ore., the past eight years. Before that time he had experience in various positions on the Deschutes, Umatilla, Malheur, and Umpqua forests and with the Pacific Northwest Forest and Range Experiment Station. His employment by the Forest Service extends over the period


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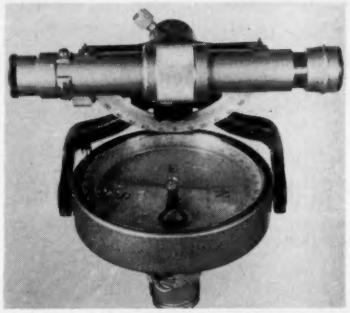

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of 24 years.

Since November 1953 Bowerman has been the district forest ranger of the Tieton district of the Snoqualmie National Forest in Washington. He entered the Forest Service in 1927 with seasonal employment on the Willamette National Forest. He continued to work on the Willamette and in 1934 received an appointment as forester. In 1937 he was transferred to the Umpqua National Forest in Oregon as district ranger in charge of the Diamond Lake district. From 1940 to 1953 he was district ranger on the Page Creek and Illinois Valley area of the Siskiyou National Forest in southwestern Oregon.

CLARENCE F. KORSTAIN

## J. L. Wenban Becomes Supervisor of Roosevelt Forest

James L. Wenban, personnel officer in the Denver Regional Office of the Forest Service, has replaced Gerald D. Pickford as supervisor of the Roosevelt National Forest, Fort Collins, Colo., Regional Forester Donald E. Clark has announced.

Mr. Pickford transferred to a staff position in the Division of Recreation and Lands, Regional Office of the Pacific Northwest Region.

Mr. Wenban is a graduate of New York State College of Forestry. His Forest Service career started in the California Region in 1937. After a series of moves in government employment, including four years' service with the Navy from 1942 to 1946, he was promoted and transferred in 1953 to the Alaska Regional Office in Juneau. He was again promoted in 1956 and transferred as personnel officer to the Denver Regional Office.

## Education

### C. F. Korstian Retires from Duke Faculty

Clarence F. Korstian, first dean of the Duke University School of Forestry, retired from the Duke faculty in August.

Dr. Korstian served as dean of the School of Forestry from 1938 until 1957. In 1929 at the request of William P. Few, then president of Duke, Dr. Korstian prepared a report recommending that the forest of several


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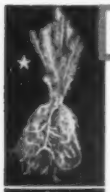

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thousand acres adjoining Duke's campus be managed as a business and for gradual development of a curriculum which would offer graduate degrees in forestry. Dr. Korstian was then invited to become director of the forest, which now totals 7,200 acres. He held that post from 1930 until his retirement.

Born in Saline County, Nebr., Dr. Korstian holds the B. S. in forestry and master of forestry degrees from the University of Nebraska, the M.A. degree from Southeastern Christian College in Georgia, and the Ph.D. degree from Yale.

In 1921 he moved from the Far West to the Appalachian Forest Experiment Station (now the Southeastern Forest Experiment Station) at Asheville. After a promotion in 1928 he assumed duties that involved forestry work throughout most of the South and East.

Dr. Korstian was president of the North Carolina Academy of Science in 1949-1950 and was named to the North Carolina Resource-Use Education Commission in 1950. He is the author of various scholarly publications, including two text and reference books. He served two terms as president of the Society of American Foresters from 1938 to 1941.

### Maki, Bethel to Head New Departments at North Carolina

Two departments have been created within the School of Forestry at North Carolina State College, Raleigh. According to Dr. R. J. Preston, dean of the School of Forestry, Dr. T. E. Maki and Dr. James S. Bethel will head the new Departments of Forest Management and Wood Products respectively.

Dr. Maki is the Carl Alwin Schenck Distinguished Professor of Forest Management at the college, and Dr. Bethel is serving as acting director of the North Carolina State College Graduate School, director of the Wood Products Laboratory, and professor of wood technology.

### Turner Visits Iran Ranger School

Lewis M. Turner, dean of the College of Forest, Range, and Wildlife Management, Utah State University, Logan, returned late in August from a two-month tour in Iran.

While in Iran, Dean Turner visited a national ranger school which he had planned three and a half years ago under the auspices of Point IV and which opened in the summer of 1957. He assisted in establishing a summer camp and studied the future equip-


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ment, building, staff, and curriculum needs of the school.

The trip was made under the auspices of ICA at the request of the Minister of Agriculture of Iran.

### University of Massachusetts Adds to Staff

The University of Massachusetts has announced the appointment of Dr. Harold B. Gatslick as an associate professor in the department of forestry and wildlife management.

Dr. Gatslick will be responsible for developing the departmental program in wood technology and utilization. In addition to teaching, he plans to devote one-third of his time to research and extension programs with industry.

Dr. Gatslick received his degrees from the State University College of Forestry at Syracuse University, Syracuse, N. Y., and was awarded his Ph.D. in 1954.

### Four Join API Staff

Appointments of four new staff members in the Alabama Polytechnic Institute School of Agriculture and Agricultural Experiment Station have been announced by Dr. Ralph B. Draughon, president.

Dr. Rudolf W. Becking has been named associate forester and associate professor in the department of forestry. Becking is a native of Wageningen, Netherlands, a graduate of the Agricultural University, Wageningen, and the University of Washington. He has been graduate assistant at both these universities and assistant professor at the University of New Hampshire and Pennsylvania State University. Dr. Becking has also worked for forest services in Indonesia, Switzerland, and Scandinavia.

John Benjamin White, native of Homewood, Ala., is instructor in forestry. He received a B.S.F. degree from the University of Georgia and M.F. from North Carolina State College. He worked for the A. K. Wood Lumber Company, Birmingham and as public service forester and forest editor in Hattiesburg, Miss.; forest consultant; and was with the Roy O. Martin Lumber Company, Alexandria, La.

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James Lamar Teate is instructor and assistant in forestry. He is a native of Cordele, Ga., and received both B.S.F. and M.F. from the University of Georgia. He has worked with the Florida Forest Forest Service.

Donald E. Smith, a 1955 graduate of API in forestry, has been appointed assistant in forestry at the Fayette forestry unit. Smith is a native of Florence and a St. Regis paper company scholarship winner his junior year at API.

### Afanasiev Gets Ethiopian Assignment

Michel Afanasiev, associate professor of forestry at Oklahoma State University, Stillwater, has been transferred on a temporary basis to the Imperial Ethiopian College near Dire Dawa to start research and teaching of forestry there.

The College of Ethiopia was organized by the Oklahoma State University under the Point Fourt program and is administered by the University.

In his forestry work in Ethiopia, Professor Afanasiev will work closely with Dr. Franz Heske, consultant in forestry to the Ethiopian government.

### Pack Foundation Aids Watershed Education Program

The Charles Lathrop Pack Forestry Foundation of Washington, D. C., has announced approval of a grant of $100,000 to the University of New Mexico, Albuquerque, for public education in problems related to New Mexico's water and watersheds.

Aspects to be dealt with include water yield of watersheds, and conditions affecting their soil, range, timber, wildlife, and recreational potentials. The program, for interested citizens generally, will include an educational TV series, production of a color motion picture, a non-credit evening course with gratis tuition, and preparation of study guides for citizens and high schools and junior high schools.

### Woods to Teach at Duke

Frank W. Woods has been appointed assistant professor of silviculture in the School of Forestry, Duke University, Durham, N. C.

Dr. Woods moved to Duke from the Marianna, Florida Research Center of the Southern Forest Experiment Station where he was research forester for the past five years. He has also taught at the Universitly of the South and the University of Tennessee.

Dr. Woods, a native of Covington, Va., received the B.S. degree in forestry from North Carolina State College, and the M.S. and Ph.D. degrees from the University of Tennessee.

### Walker Granted Leave to Study Fertilization Research

Through special arrangement with the University of Georgia, Laurence C. Walker, associate professor of forestry, has accepted a temporary appointment as chief forester for the National Plant Food Institute, Dr. Samuel L. Tisdale, Southeastern regional director, has announced. The appointment became effective July 1.

Dr. Walker will be on leave from the University of Georgia for this special assignment.

His primary responsibility will be to summarize and evaluate forest fertilization work currently under way in the Southeastern states and to explore the need for a coordinated program of research activities in this field.

Dr. Walker, a native of Washington, D. C., obtained his B.S. degree in forestry from Pennsylvania State University, his M.F. from Yale University, and Ph.D. degree in forest soil chemistry from the New York State College of Forestry at Syracuse University.

### Richardson Foundation Gives Graduate Fellowship

Director David S. Weaver of North Carolina State College's Agricultural Extension Service has announced the establishment of a special $6,000 fellowship to train a forest insect and disease control information specialist for North Carolina.

The fellowship was awarded to Fred E. Whitfield, a veteran member of the Extension Forestry staff.

He will take graduate training at the State University College of Forestry at Syracuse University, Syracuse, N. Y.

The Richardson Foundation of Greensboro, N. C., is making this fellowship available to the State Extension Service through the North Carolina State College Foundation.

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### Two Added to Humboldt Staff

The appointment of two new members to the staff of the Division of Natural Resources at Humboldt State College, Arcata, Calif., has been announced by Charles F. Yocom, division chairman.

Henry A. Froehlich will teach courses in logging engineering, photogrammetry, and related subjects. Mr. Froehlich, who received his bachelor's degree in forest engineering from Oregon State College, has spent the past six years as unit supervisor and logging engineer in the North Coast region of California. He moved to Humboldt State College from the Simpson Redwood Company.

Charles F. Cooper will teach range management and ecology. He received his bachelor's degree in forestry from the University of Minnesota in 1950, and was subsequently employed in forestry and range management in Colorado and Arizona. He earned his M.S. in range management at the University of Arizona, and recently completed his Ph.D. at Duke University.

### Purdue Assistantships Available

William C. Bramble, head of the Department of Forestry and Conservation at Purdue University, Lafayette, Ind., has announced the availability of two graduate assistantships in the field of marketing forest products.

Students who wish to emphasize forest management or some phase of wood utilization will be eligible so long as they are willing to do assistantship work in marketing. Assistantships pay $170 a month with fee remittances.

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## Positions Wanted

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**Box Y, Journal of Forestry, Mills Building, Washington 6, D. C.**

Forester, B.S.F., 1956. Age 24, married, one child. Experience: four seasons fire control; one summer cruising for timber purchase; six months using aerial photo interpretation and cruising. Military obligation completed in December 1958. Desire position in western Washington or Oregon.

**Box A, Journal of Forestry, Mills Building, Washington 6, D. C.**

Forest Pathologist, Ph.D. 1925. Age 64, excellent health. 35 years teaching and research experience. Desires temporary teaching or research assignment for one term or more. Will consider any location.

**Box B, Journal of Forestry, Mills Building, Washington 6, D. C.**

Forester, graduate Penn State and Duke. Family man. 11 years experience: worked as research forester and forest manager in both public and private fields; skilled in forest management, silviculture, mensuration and regeneration; supervised logging jobs for the production of veneer sawlogs, piling, and pulpwood; directed forest inventory and stand improvement work. Desire position with progressive organization.

**Box C, Journal of Forestry, Mills Building, Washington 6, D. C.**

Forester, B.S., age 38, married, one child, veteran. Twelve years experience in municipal park and forestry operation. Desire employment in forest management, pulp manufacturing or procurement, fire control, reforestation, nursery or related work in Alaska, the vicinity of Anchorage and the Kenai Peninsula preferred.

**Box D, Journal of Forestry, Mills Building, Washington 6, D. C.**

Forest Utilization graduate, 1954; expects to complete work on M.S. in Forest Management December 1958 at Colorado State Univ. Completed 3 year tour in service. Age 27, married, health excellent. Experienced in logging, surveying, fire suppression, photogrammetric work, and Forest Management Research. Desire position with private industry in western states.

**Box E, Journal of Forestry, Mills Building, Washington 6, D. C.**

B.S., Forest Mgt., 1957. Age 27, single, veteran. 8 months with private industry, presently 18 months with U.S.F.S., plus summer experience. Desire job with less dampening by red tape and formalities. Consider anything legit in any location, including overseas. Will travel. Have references.

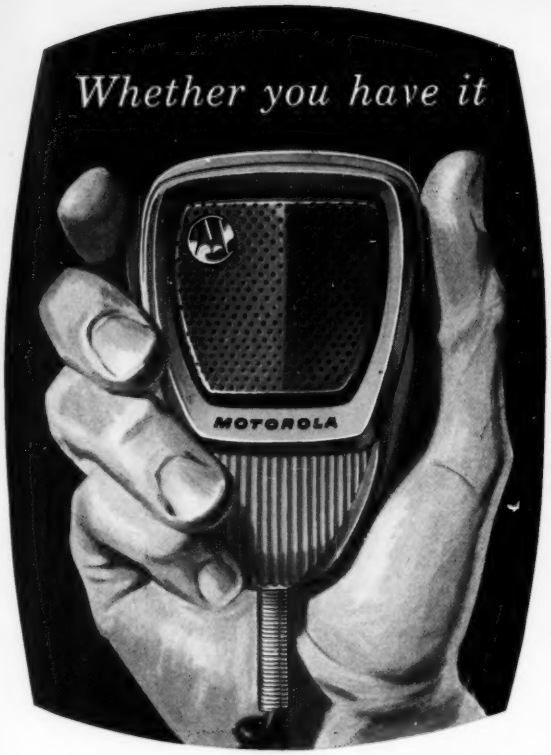
**Box F, Journal of Forestry, Mills Building, Washington 6, D. C.**

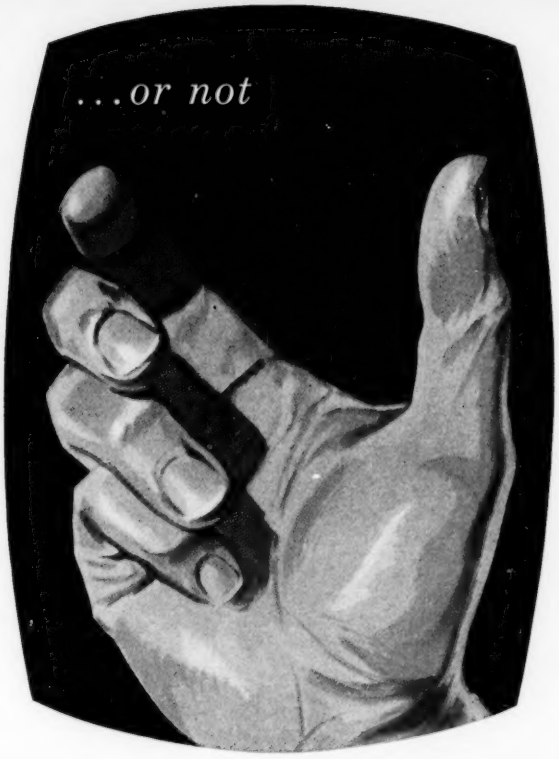
Forester, B.S., Forest Management, 1952, North Carolina State College. Age 34, married. Experience includes 6½ years Forestry Extension work, Private Consultant, Farm Forestry, and Fire Control in the Southeast and the Northwest. Prefer position in the Southeast but will consider other locations.

**Box G, Journal of Forestry, Mills Building, Washington 6, D. C.**

Forester, B.S. 1951, La. Polytechnic. Age 34, married, 3 children. Four years forest management with a southern State Forestry Comm. Two years managing 30,000 acre tract, all phases. Must relocate because of leg injury which will limit woods walking. Desire position in management, research, lumber sales, utilization, or preservation.

**Box H, Journal of Forestry, Mills Building, Washington 6, D. C.**

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That's right! The new Homelite 7-21 chain saw is designed to help you make more money, faster. Its big fuel tank lets you cut longer without refueling. Its balanced 21 pounds* means easier, safer handling in any location, any cutting position . . . lets you cut with less effort. The rugged gear drive delivers enough lugging power to fell trees up to 7 feet in diameter; speed to cut through 20" trees in 18 seconds.

A real professional's saw, the 7-21 has 7 magic features that mean greater dependability, longer life, less maintenance. These features include the famous Homelite high compression, short-stroke engine that delivers full power in any cutting position . . . automatic governor to maintain proper chain speed . . . large air filter to keep out sawdust, dirt and snow . . . simple piston pump oiling . . . tough, drop forged counterbalanced crankshaft to assure smooth running with less operator fatigue.

A full line of attachments is available. The plunge-cut bow — 14" and 18" — is ideal for cutting pulpwood . . . the brush cutter converts your 7-21 to a power scythe in minutes . . . the clearing bar makes the 7-21 a handy, fast-cutting clearing tool.

Get in the money making picture! Find out for yourself by seeing a free demonstration of the Homelite 7-21 chain saw at your nearby Homelite dealer's.

*less bar and chain

**And the Homelite 7-21 is guaranteed for a full 7 months!**

**HOMELITE**

**A DIVISION OF TEXTRON INC.**

**4111 RIVERDALE AVENUE, PORT CHESTER, NEW YORK**

*Manufacturers of carryable pumps, generators, chain saws, blowers.*

*In Canada: Terry Machinery Co., Ltd.*

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